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BRITISH FORESTRY

BY R. L. ROBINSON

IN this, the first number of a Journal devoted to the technical side of British Forestry, it is desirable to consider briefly the limitations under which the practising forester works. In the first place, the results of his labours accrue not to himself but to another, whether a private individual or the State. In the second place, the final results are long in coming; it is rarely the forester's lot to observe the end result of work which he has initiated. His whole experience is a mosaic, built up partly of his own successes and failures, partly in dealing with or in observing the successes and failures of others. Needless to state, the pieces of the mosaic never fit exactly, and the conscientious individual must be prepared to admit the fact. In the third place, forestry is either wholly or in part, according to local circumstances, a commercial undertaking. Perfect technique can sometimes be obtained only at too great a price.

It is proposed to develop each of these heads in a little detail, but it may be observed in passing that the man who strives to become the perfect forester has set up for himself a high and worthy ideal: he is to work not only for his bread and butter (which may be available in sufficient quantity, but certainly not in superfluity), not only for others, but also for future generations. In keeping a just balance between the present and the future, between the work which is accessible from the ride side and that which is remote, he is to resist every temptation merely to 'make a show' or to be content with shoddy work.

FOREST POLICY.

Current Policy. The general limitations under which a forester exercises his profession are set by Forest Policy in the case of the State, and by the will of individual forest owners. With one or two slight exceptions, it was the accepted policy of Great Britain, up to the Great War, to regard forestry mainly as the business of the private individual and not of the State. The exceptions are the attempts to grow oak in the Crown Woods early in the eighteenth century, and again early in the nineteenth. Right through the nineteenth century the private owner continued to manage his woods with but little official guidance, and in the face of changing conditions which, in the coppice and hardwood areas of England at least, left him but little or no margin of profit. Nevertheless, it is from private plantations formed during this period that most of the basic data as to the rate of growth of trees in this country have been collected.

The State began to display a more general interest in forestry in the last two decades of the nineteenth century by promoting forestry education, by some small-scale afforestation work, and by placing the Crown Woods under systematic management. During the first decade of the twentieth century it was continuing to inquire into the subject, prepared to approve of projects for education and research, but still loath to participate actively in timber growing. At this stage the State (Crown) owned approximately 5 per cent. of the three million acres of woodland in Great Britain.

During the War the imperative demands for timber forced the State to intervene in private woodlands with a heavy and destructive hand. The data available are not precise, but it appears that from 450,000 to 500,000 acres of

woodland were felled during or immediately after the War, yielding approximately one thousand million cubic feet of timber. This practical demonstration of the value of the home forests was worth unlimited speculative argument, and it was agreed by all the political parties that the time had come for constructive action on the part of the State. Briefly, the policy adopted by the Coalition Government, on the advice of the Acland Committee, was the maintenance of the three million acres of pre-war woodland in a productive state, and the addition thereto, by afforesting uncultivated land, of one and three-quarter million acres of coniferous plantations in the course of eighty years. An underlying principle was that the task should be adjusted from time to time between the State on the one hand and private and municipal owners on the other. For the first decade the former was to plant 150,000 acres with conifers and a small but unspecified area with hardwoods; the latter were expected to plant 110,000 acres (partly with State aid), making a total of 260,000 acres. To carry out this programme and ancillary work the Forestry Commission was established in 1919, under the chairmanship of Lord Lovat, with the promise of three and a half million pounds to finance the first ten years' operations. The work made a good start, was checked in 1921 and 1922 on the recommendation of the Geddes Committee on Economy, was speeded up again in 1924, when the policy of forming forest-workers' holdings was added, and has continued steadily to the present date.

Two planting seasons have yet to run before the decade is completed, but it seems probable that against the 260,000 acres of new plantations to which the Acland Committee looked forward, some 230,000 acres should be realized.

Future Policy. The policy recommended by the Acland Committee was drawn up in 1916-17, when the full extent of the war fellings was not foreseen, and under circumstances which made it impossible to secure reliable data. The position is now better known, since an accurate census of woodlands has been conducted by the Forestry Commissioners in the interval.¹ Briefly, the main points in the position in 1924 (the date of the census) are as follows:

(1) The total area of woodland was 2,960,000 acres, and of this less than half

¹ *Census of Woodlands, 1924.*

I. Economic or potentially productive:

	AGE CLASSES					TOTAL
	1 to 10 years	11 to 20 years	21 to 40 years	41 to 80 years	Over 80 years	
	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
Conifers	105,020	98,030	153,940	244,520	70,330	671,840
Mixed conifers and hardwoods.	10,720	15,950	63,430	134,410	77,180	301,690
Hardwoods	4,940	10,470	39,160	180,540	208,230	443,340
<i>Total</i>	120,680	124,450	256,530	559,470	355,740	1,416,870
Coppice, and coppice with standards						528,670
Scrub						330,700
Felled and/or devastated						478,100
II. Uneconomic (including amenity woods, shelter belts, park timber, etc.).						204,290
<i>Total</i>						2,958,630

(1,417,000 acres) is high forest. The remainder includes 330,000 acres of scrub, 478,000 acres felled and devastated, 204,000 acres of amenity woodland, shelter belts, &c., and 528,000 acres of coppice and coppice with standards.

In the high forest category were 672,000 acres of conifers, 302,000 acres of mixed conifers and hardwoods, and 443,000 acres of hardwoods.

(2) The reserves of mature timber in the country were mainly hardwood, of which there were 208,000 acres over eighty years of age, against 77,000 acres 'mixed' and 70,000 acres conifers in the same age class.

(3) As regards the younger age classes the outstanding point was the dearth of hardwoods: there were only 15,000 acres aged 1 to 20 and 39,000 acres aged 21 to 40. The planting of hardwoods has in fact gone almost completely out of fashion, and at the present rate augurs ill for the maintenance of supplies.

(4) The total rate of planting by private individuals seems to have averaged about 12,000 acres per annum over the last forty years.

The data provided by the Census of Woodlands should be given careful consideration in deciding on the State policy for the decade 1929-39. Assuming that in 1929 the State is planting at the prescribed rate of 30,000 acres (of conifers) per annum, what progress is likely to be made towards the ultimate programme recommended by the Acland Committee? The contribution by private owners of forest can be written off by saying that they will not replant more than they fell (the present tendency is to fell year by year a good deal more than is replanted). In order to reach the first stage in the Acland scheme (3,000,000 acres of effective woodland) it will be necessary for the State to plant in round figures 1,500,000 acres, which, at the rate of 30,000 acres per annum, would take fifty years. The replacement of only the existing felled area, amounting to 478,000 acres, would take sixteen years.

There is no need to go into these figures in further detail. It is an interesting exercise which any forester can do for himself, to take the summary figures of the Census of Woodlands, and to determine what area should be planted or otherwise regenerated, annually, in order first of all to bring the existing woods into a productive condition within a reasonable time, and secondly to add the 1,750,000 acres of new forest. It will then become clear that if an adequate reserve of growing timber is to be maintained in this country, the State will have to come more and more into the business, and that the scale on which it should operate is likely to be influenced less by the rate of planting which is deemed desirable than by financial considerations.

FORESTRY TECHNIQUE.

It is not intended to go into details regarding silvicultural methods and procedure, which are dealt with by Mr. Guillebaud and Dr. Steven. In the opening paragraph reference was made to the mosaic constituting the forester's experiences. This characteristic is particularly true of our knowledge of one of the basic subjects, namely, rate of growth of different species under different conditions, and conversely the production to be expected from different types of ground not hitherto under forest. The importance of precise knowledge cannot be exaggerated: it is as essential to the forester as knowledge of the strength of constructional materials is to the engineer. With so many coniferous species which do reasonably well if placed in the correct locality conditions, and with such rapidly varying conditions as occur in Great Britain, many

years must elapse before the whole position can be satisfactorily defined. In the meantime there is ample room, apart from the extensive investigations of the Forestry Commissioners, for accurately observing and recording data.

Probably the greatest advances which have been made in recent years are in connexion with poor sites, chiefly through ecological studies. *Molinia* peats can now be dealt with. The next but more difficult step is to learn how to treat the heather types of moorlands.

As regards the choice of exotic species in coniferous plantations, we have still a great deal to learn. Sitka spruce is proving a most adaptable and productive tree; Japanese larch is giving unexpectedly good results under the wet and exposed conditions of the west coast; *Pinus contorta murrayana* may very well prove to be the maritime type which is required in place of mountain pine in this country for mixing with spruces on poor sites; Douglas fir has suffered considerably from wind and snowfall in dense stands and on wet ground, otherwise it grows as well in this as in its native country; other interesting species, such as Lawson's cypress, *Cupressus macrocarpa* (on the south coast of England), *Thuja plicata*, and *Tsuga heterophylla*, are also worth watching.

It is a question which requires attention, whether the present tendency towards pure coniferous plantations is not going too far. This and allied matters, such as planting distances and thinning, will no doubt receive detailed attention in subsequent numbers of this Journal, and it is unnecessary to anticipate them.

As regards hardwoods, the forester of to-day is left with an unenviable heritage. The system of heavy thinning, which was prevalent until about thirty years ago, has left crops which are rapidly deteriorating and are difficult to regenerate at a reasonable cost. Yet regeneration on a considerable scale is necessary if a continuous supply of hardwoods is to be maintained.

As regards the health and protection of forest crops a constant watchfulness has to be maintained, especially in regard to the valuable exotics Douglas fir and Sitka spruce. So far British forests form a relatively healthy community but subject to many minor ills which can mostly be dealt with by sound hygiene.

Briefly, the note which it is desired to sound in this brief sketch is that, while it is necessary to go ahead with large-scale operations, there is a great need for research work and forest investigations and for the application of experimental results to practice.

UTILIZATION.

It is an apparent anomaly that whereas Great Britain imports annually roughly ten million loads of timber, valued at fifty million pounds, it is often difficult to dispose of parcels of home-grown timber. There are a number of reasons, among which may be mentioned: on the one hand faulty silvicultural methods, the small size and mixed character of many parcels, the irregularity of fellings, and on the other hand mediocre methods of conversion, seasoning, and marketing. There ought in fact to be a market for every stick of home-grown timber, and on a very few estates, where utilization has been developed over a long series of years, this desirable state of affairs has been reached. The investigations of the Forest Products Research Laboratory are beginning to show, as experience has already shown in the case of oak, ash, and other British hardwoods, that intrinsically our coniferous timbers are suitable for all ordinary

commercial purposes. It is reasonable to conclude that when they are available in bulk year by year, and the utilization side has been suitably organized, they will compete on favourable terms with imported timber. Before the conversion stage is reached, however, and in the course of the next fifteen to twenty years, the considerable areas of plantations now being formed will be yielding small thinnings. The utilization of this produce will be a considerable undertaking, but it is believed that there will be no difficulty in disposing of it to the mines and elsewhere.

THE SILVICULTURE OF CONIFERS IN GREAT BRITAIN

BY H. M. STEVEN

IN this article we shall use the term silviculture in a broad sense and present a general study of the growth of our different coniferous species, their regeneration, and tending. Of necessity this must be a mere outline, because even in Britain the tale of the forest is a long one. As the silviculture of coniferous woods in this country can scarcely be viewed in perspective without the past as a background, we will begin by considering its evolution.

There is much post-glacial forest history entombed in our peat bogs. The presence of tree remains in them has been known for centuries, but their scientific study dates from this century, when they were investigated by Lewis (17), Samuelsson (25), Woodhead (33), Erdtman (8, 9), and others. To begin with, the stumps, trunks, and cones were studied, but in later years, under the inspiration of von Post and other Scandinavian geologists, increasing attention has been paid to the presence of pollen of different species. In order to understand the sequence of the general history since glacial times, Blytt's nomenclature of the different periods may be given. They are arctic, boreal, atlantic, sub-boreal—the end of which is synchronized with the Bronze Age—and sub-atlantic, which falls into historical times. Investigations both in England and Scotland have shown that birch was the first dominant tree in the early part of the boreal period; indeed this species has played an important part throughout our forest history. Pine followed, but in England, and probably the Southern Uplands, it did not appear to be an important species for long, because it is considered probable by Erdtman and Woodhead (33) that the pine forests disappeared in late boreal or early atlantic times. At this time the alder immigrated, with hazel, elm, oak, lime, beech, and hornbeam. This is shown, for example, by Erdtman's (9) pollen diagram for Chatmoss, Lancashire. In the bogs of the central and the north-west Highlands of Scotland the percentage of pine pollen does not show the same marked fall from the deepest layers of peat upwards, and there are abundant remains of pine in peat which was formed probably in sub-boreal time. The pine is almost always found with birch, and on the west coast alder is also an important associated species.

At the dawn of the Christian era, although Scots pine (*Pinus sylvestris* L.) may have been present as a very subsidiary species in the forests of at least the northern half of England, the southern uplands, and the east coast lowlands of Scotland, it appears probable that the only pine forests were within the Scottish Highlands. Even there, however, there is evidence that they were less extensive than at an earlier post-glacial epoch. Except for this relatively limited region, our natural forest was not coniferous, and even there birch and other broad-leaved trees were important constituents.

Until the Middle Ages little is known regarding these comparatively inaccessible pine forests. They probably did not suffer much destruction by man, for in the Scottish Parliament assembled in Edinburgh in 1609 there was joy at the discovery of woods in the Highlands. During that period, however, there was no doubt a gradual, if slow, decrease of land under forest and a corresponding increase of treeless moorland and bog, which in some cases may be attributed to storms. It is interesting to note that Walker (31) states that the Earl

of Cromartie saw a wood of old, dying, Scots pine at Loch Broom, Western Ross-shire, in 1651. When he revisited it in 1699 the site had become a bog, and the peat and the tree remains were being used for fuel. Storms have always been destructive, and Ritchie (24) quotes an instance of a wind-blown pine forest in a peat deposit at Coldstone in Aberdeenshire.

From the Middle Ages until to-day the natural coniferous forests have been gradually utilized for various industrial and domestic purposes, or cleared for sheep grazings. Ritchie (24) and Richardson (23) may be consulted for a more detailed modern view of this period. The larger natural Scots pine forests, which have come down to our times, are Glenmore, Rothiemurchus, and Abernethy, all in Upper Strathspey, Inverness-shire; Ballochbuie in Upper Deeside, Aberdeenshire; Rannoch in Perthshire; Glenmalie, beside Loch Archaig, and Glen Affric, both in Inverness-shire; and a few smaller ones farther west, such as Rhidorroch, near Ullapool, in Western Ross-shire. According to Grigor (13), Glenmore was cut over during the twenty-two years from 1783, partly for shipbuilding, and was again felled during the War. Rothiemurchus and Abernethy also yielded a large return a century ago, the revenue of the former often exceeding £18,000 per annum. What remained of Glenmalie Forest was cut just before and after the War.

The sixteenth century saw a new epoch open in the history of our coniferous forests, namely, the beginning of the introduction of species not indigenous to this country. According to Elwes and Henry (7), *Pinus pinaster* (Ait.) and Norway spruce (*Picea excelsa* Link.) were introduced during the sixteenth century. They must have been unknown or very rare in 1534, because Fitzherbert (12) does not mention coniferous species, although he discourses on woodland husbandry. In 1629 Parkinson (22) describes and figures Scots pine, larch, spruce, and cypress, while in 1662 we find Evelyn (10) in his well-known *Sylva*, writing on *Abies*, *Picea*, *Pinus*, *Larix*, and hemlock, in such detail as to make their identification certain.

It was probably not until about the beginning of the eighteenth century that a coniferous species was planted in this country as a wood or forest for production as distinct from ornamental purposes, and appropriately the first species so planted was Scots pine. This marked the beginning of the extension of coniferous species in Britain and of their rise to a dominant place. There is a magnificent planted stand of Scots pine, which is almost two hundred years old, round Castle Grant, at Grantown, Speyside. One felled tree there, which the author measured some years ago, was over 100 feet high. A notable planter at the beginning of the eighteenth century was the then Earl of Haddington (14), who began planting at Tynningham in 1705. He also wrote an informative *Treatise on Forest Trees*. To begin with, he imported the Scots pine cones from the Highlands, and has something to say about the danger of overheating them during extraction. The highlanders did overheat the seed, and there appears to have been a regular trade in pine seed. He advocated thick sowing, preferring the seedlings to come up like 'cress'. He used two-year seedlings for planting, although transplanting was practised by others. His method of planting was practically identical with our vertical notching, while he pared off the turf where the grass was rank. Later he gathered the cones from his own trees; and he considered that there were two types of the species, one with a deeper red heartwood than the other, the former of which he preferred. It seems probable

that many of the plantations of Scots pine in the Borders, such as at Mellerstain, Langlee, and Birkenside, which were felled during the War when 100 to 150 years old, were descended from a good Highland type of Scots pine. Sample plots¹ measured at Langlee gave the age as 123 years, the mean height 90 feet, and the underbark quarter girth volume per acre over 8,000 cubic feet. The trees had the characteristics of our native pine.

Towards the end of the same century Scots pine began to be planted in the south of England, in the New Forest, the Wiltshire Downs, and elsewhere. On the Waverley estate, near Farnham, Surrey, a sample plot of Scots pine was measured during the War. The age was 141 years, hence the plantation dated from this period, the mean height was 92 feet, and the underbark quarter girth volume 9,300 cubic feet.

The eighteenth century also saw another important epoch in the history of our coniferous forests, namely, the introduction of the larch (*Larix europea* DC.) into Scotland, and its extension there and in England. In recent years Schotte (26), in Sweden, and Opperman (21), in Denmark, have written on this subject. Their object has been to trace the source from which the seed came, because of the silvicultural excellence of the old Scottish larch. The silvicultural points on which information is required are two, the origin of the seed or plants of larch introduced into Scotland, and whether our older larch plantations were derived from seed of the earlier introductions and thus relatively homogeneous in origin. Through the courtesy of Sir John Stirling Maxwell, I have been able to consult two of the earliest publications which deal with the larch in Scotland, Anderson's (1) *Essays on Agriculture*, vol. iii, 1796, and the *General Report of Scotland* (27), vol. ii, 1814, as well as the later accounts, namely, the one by Walker (31), 1812, that by Trustees of the Fourth Duke of Atholl (2), 1832, and Loudon (18), 1838. Although there are many claimants for the honour of being the first to have introduced the larch into Scotland, there is no information regarding the origin of seed or plants, except the statement, in the Atholl account, that, in 1738, Mr. Menzies of Megeny, in Glenlyon, brought a few small plants of larch in his portmanteau from London, five of which he left at Dunkeld and eleven at Blair Atholl. We do not know whether the plants were of direct continental origin, or were raised from seed collected in England, where there were larch trees bearing seed. Further introductions must have been made, because a further 1,925 plants were planted on the Atholl estates by 1759, and it is recorded that it was not until about 1766 that trees at Blair began to bear cones. It is stated in *The General Report of Scotland* (27) that the father of Sir Archibald Grant of Monymusk brought seed of larch from the Duke of Atholl's estate in 1758. In this case, therefore, there was connexion with the Atholl introduction. Later, in the eighteenth century, larch plants became plentiful, and Anderson (1) stated (1796) that the nurseries were full of them, one in Edinburgh having five millions. Considering that Scottish larch seed to-day yields only a few thousand plants per lb., it is scarcely credible that these were all raised from Scottish seed. However, in the methods of nursery practice used at Dunkeld and in commercial nurseries, as given by Anderson (1), cones and not seed are talked about. Further Grant (27) stated that the larch bears cones at seven years, and owing to the construction of a machine for cutting the cones to pieces, larch seed fell in price from 10s. 6d. to 10d. per lb. The balance of

¹ Data from Forestry Commission sample plots, quoted by permission of the Commissioners.

evidence, therefore, is probably in favour of the view that the first extensive larch plantations were derived from seed from the earlier home stock. It is interesting to note that at Culquoich, on the Seafield property, Strathspey, there is a naturally regenerated wood of larch now eighty-five years old. In this instance there must be direct succession from one of the early plantations of the species.

The Dukes of Atholl, particularly the fourth, contributed much to the silvicultural knowledge of larch. In the first place the need of relatively elevated slopes for this species was realized. We know now that larch is sensitive to exposure from the prevailing wind, and the larch at Craigvinean, Dunkeld, which was on the exposed ridge at 1,600 feet was blasted and distorted. Just below on the sheltered side the growth if slow was satisfactory, and the timber very hard and durable, although difficult to cut up. The early Atholl plantations were systematically carried out, planting plans made with roads and paths laid out, and the ground divided into units of fifty acres. Costing analyses were prepared, and the work was carried out efficiently. A form of vertical notch was used, and in later years one-year and two-year seedlings or small transplant stock was used. When plants were more abundant, pure plantations were formed, but the spacing was wide for the times, namely, about five feet. In contrast Anderson (1) advocated a spacing of two feet. The importance of early and moderately heavy thinning was realized.

Towards the end of the eighteenth century larch began to be used as a plantation tree in England, particularly in the Lake District and Wales. It is interesting to note that during the War a sample plot was measured in a larch wood at Hafod, Cardiganshire, at an elevation of 1,150 feet. The age was 115 years, the mean height 73 feet, and the quarter girth underbark volume per acre 4,970 cubic feet. This must have been one of the early Welsh plantations. The Society of Arts awarded a premium in 1786 to Thomas White for a large plantation of forest trees, more than half of which were larch, at Batsfield, County Durham. In 1788 they offered gold medals and premiums for planting larch and making known the useful properties of the timber, and one of these was awarded to the Duke of Devonshire for a large plantation in the north of England.

At the time when the larch was beginning to play an important place in our silviculture, Menzies (19), a surgeon with Vancouver on his voyage to the Pacific coast of North America, was discovering Douglas fir (*Pseudotsuga douglasii* Carr.) and Sitka spruce (*Picea sitkensis* Trantv. & Mey.). In the early summer of 1792, while cruising up the coasts of Oregon, Washington, and British Columbia, Menzies saw and described these species. The specimen of Douglas fir which he brought back, which is now in the Banksian Herbarium of the British Museum, is labelled 'Notka, Menzies'. The species which he called *Picea alba*, in the Admiralty Inlet, was probably Sitka spruce. These species were later to be of importance in our silviculture.

The middle nineteenth-century history of our conifers is reflected in the pages of Brown's (4) *Forester* and Grigor's (13) *Aboriculture*. In Scotland there was a great extension of larch plantations on every sort of site. Grigor states that the annual nursery out-turn of larch plants was twenty millions, most of these being raised from continental seed and not home collected. This he deplored, but Brown advocated this practice on the grounds that because the germination capacity of the home seed was low, the quality was not satisfactory

either. The importation of continental seed, not only of larch but also Scots pine, was a feature of this period, and even in Strathspey, the great stronghold of the native Scots pine, extensive plantations of foreign-derived pine were formed, with results which were to prove disastrous. Another feature of this period was the revival of the single-stem European larch—Scots pine mixture. Scots pine was used with the larch in the early Atholl plantations owing to the scarcity of plants, but in that fertile region the pine was quickly suppressed, and the later plantations were pure larch. This mixture of species in the nineteenth century has been attributed to Brown's influence, but he does not advocate a single-stem mixture for coniferous species, but mixture by groups, a very different practice. Grigor (13) favoured the Scots pine-larch mixture partly on the grounds of amenity, and this certainly was a notable feature of Scottish forestry during last century. Although far from an ideal mixture, it had one advantage. On most sites Scots pine does not grow so fast as larch, and thus the overcrowding of the larch crowns which would have resulted from close planting and delayed thinnings was lessened. On other sites which tend to favour the Scots pine, the mixture is not unfavourable, the two species growing at a similar rate throughout their life. An example of this was to be seen in part of Orton Wood, Lower Speyside, where on a morainic soil both larch and Scots pine attained mean heights of over 90 feet in 125 years.

In England there does not appear to have been so rapid an extension of coniferous plantations during last century as in Scotland. Indeed, we are only now witnessing an important increase of coniferous plantations in England; and particularly in the south of England these are not welcomed by lovers of the typical English woodland, which is a place of birds and flowers. In Wales, however, as in Scotland, larch was planted extensively.

Perhaps the most interesting feature of forest history during the nineteenth century was the introduction of coniferous exotics to Europe. Menzies did not bring back the seed of Douglas fir or Sitka spruce; although there were cones on the twig specimen of Douglas fir he collected, these were lost. It was left to David Douglas (5), another Scotsman who had been sent out by the Horticultural Society to North America, to bring back seed of Douglas fir, probably from Fort Vancouver, where, in August 1826, he noted 'laid in specimens of *Pinus taxifolia* with fine cones'. This seed arrived in this country in 1827. In 1830, on a second expedition, he sent home seed of Sitka spruce. He found this species 'on the bleak, cold, mountainous parts of the coast from Arguilar River in 43° to 49° N. latitude'. Plants from this collection were raised by the Horticultural Society and distributed to fellows and associated societies abroad. As far as is known, however, only a few specimen trees of Douglas fir, such as that at Eggesford¹ (7), date from that period. In 1850 a society of Scottish landowners, called the Oregon Association, sent Jeffery to America to make collections of seed. The Japanese larch (*Larix leptolepis* Murr.) was also introduced about this time, namely, by Veitch, in 1861. Greater interest was taken in exotics, and our oldest Douglas fir plantations, such as Taymount and Murthly, Perthshire; Gairloch, Ross-shire; and Tortworth, Gloucestershire, date from this time. According to ring counts, Taymount was planted in 1861 and Tortworth in 1869. Although Douglas prophesied that 'Sitka spruce would thrive in such

¹ Mr. C. O. Hanson states that the present height of this tree is 130 feet; about 20 feet at the top is dead. The girth at breast height is 202 feet.

places in Britain where even *Pinus sylvestris* finds no shelter', this species was not used in a plantation until 1882, when it was planted on exposed peat moors at Strathgyle, Durris, Lower Deeside, Scotland.

Reference must be made to two pests which have had a great influence on our silviculture, the rabbit and the brown squirrel. The former has done much to lessen natural regeneration in this country, while the spread of the latter, particularly in the pure pine forests in Scotland, has been a very notable feature of the last and of this century. There are few pine woods in the north of Scotland which have not been damaged by the squirrel, and this is one reason for the present disfavour into which Scots pine has fallen.

This century saw the return in an increasing degree to pure rather than mixed coniferous plantations, while the new exotics, particularly Douglas fir and Japanese larch, were used to a much greater extent than formerly. One reason of the growing popularity of Japanese larch was the serious damage which larch canker (*Dasyctypha calycina* Fuck.) was causing to the European species.

The War saw the reaping of last century's planting of coniferous species, because the restriction of timber importation made an unprecedented demand on our home supplies both of pitwood and saw-timber. As the great extension of coniferous species had only taken place during the second half of last century, a very heavy inroad was made into our older stands to provide really large-sized timber, and the available supply of this class of timber has in consequence been much reduced. This from a silvicultural point of view is unfortunate, because the continuity of race of our native pine and earlier-introduced larch is now much less than what it would otherwise have been. In the stress of war-time felling also, clear cutting was the only method possible, and artificial regeneration was again made necessary.

This brief and necessarily incomplete outline of our coniferous history tends to bring out certain features of our own time which are somewhat obscure. We see that our natural coniferous forest was always confined to a relatively small part of Britain, the central and north-west Highlands of Scotland. It was at its maximum extent long before historic times, and there has been a retrogression to moorland, due, it may be, to climatic deterioration. The extension of coniferous woods from the eighteenth century onwards outside that region was on land which had never carried a predominantly coniferous crop in post-glacial times. In many instances the land had not carried any kind of forest for centuries, while during that period it had undergone far-reaching changes due to grazing, burning, or other use, and had ceased to have the characteristics of forest. Our first artificial pine forests were probably largely, if not wholly, of native origin. Then followed the introduction of the exotic species, larch, with spruce used sparingly about the same time. Last century saw heavy importations of continental pine seed, and later in the century the beginning of the use of the newer exotics in plantations. Therefore our coniferous forests are artificial in a peculiar degree. Our method of formation has been almost wholly artificial, largely through necessity, the tradition so formed continuing the method when natural regeneration might have been followed. Further, our sites outside the Highland area are artificial for conifers, in that the natural forests, if any, which once covered them were not coniferous. Again, exposure to the prevailing wind has an unusually important influence on tree growth in this country, and the influence of this factor varies in different species and at

different ages in the same species. These considerations make it necessary for us to base the use of our species on the results of the growth, timber quality, and health, which they have shown under different conditions. We will now consider some of the salient features of our principal coniferous species.

Scots pine. Scots pine has played two different roles in this country. It has been used to form pure or almost pure plantations, and it has been employed as a subsidiary species in mixed forests. Plantations of Scots pine have been established on all sorts of sites, but the really extensive ones are on the lighter soils, such as the sands and gravels. It is notable that our remaining natural forests are largely on such soils, for example, those in the Dee and Spey valleys, and Glenmalie Forest in the west. Our most typical Scots pine regions in Scotland are in the valleys of the Dee, Spey, and Findhorn, where the natural forests have been largely supplemented by plantations of the same species. Details of the typical floristic character of such an area may be found on page 119 of *Types of British Vegetation* (30). The characteristic plants are *Calluna vulgaris*, which is dominant over large areas, *Vaccinium myrtillus*, and *V. vitis-idaea*. Typically the soils are light and have been transported from the great granite plateau, the Cairngorms. The mean annual rainfall varies from 30 to 50 inches, but much of the area has a rainfall of less than 40 inches per annum. In the upper valleys the growing season is shorter than elsewhere, and snowfall is definitely a feature of the winter, unlike most of our island. The Grampian mountains form an important barrier to the prevailing south-west wind, hence the region is relatively sheltered. The distribution of Scots pine woods in this region is from sea-level to 1,500 feet, the majority, however, being under 1,000 feet. Grigor notes that subsequent to 1860 there were large importations of Scots pine seed from the continent. We have many middle-aged plantations in which the trees differ markedly in type of branching and in other respects from those of our indigenous types. We cannot go into this subject here, but the indigenous types while variable are generally of the *lapponica* type. Particularly in regions liable to snowfall, the foreign types have been unsatisfactory, and, further, the purity of our own indigenous strains has been contaminated.

The variation in the rate of growth of Scots pine in this region covers practically the range of difference found in this country. Particularly in Lower Speyside, on relatively fertile soils and in sheltered positions, there has been remarkable production of Scots pine, for example, at Orton, where at 125 years mean heights over 90 feet and underbark quarter girth volumes per acre of 10,000 cubic feet have been produced. These pines had conical crowns and were almost certainly of native origin. The outer zone of timber was good, but the presence of dead knots in the interior detracted from its quality for certain purposes. At the other extreme there was the very slow growth in Glenmore natural forest at over 1,000 feet above sea-level. The majority of the trees were about 150 years old and the height rarely exceeded 60 feet. As usual in a natural forest, growth was very slow during the first twenty years, while the culmination was between 80 and 100 years. Where the trees had grown up under canopy conditions the timber was excellent. The Scots pine timber in this region, both from natural and planted woods, has been studied by Horne (16).

A feature of this region is the freedom with which Scots pine regenerates naturally, and if it were not for grazing and periodic burning, the area of natural wood would be much larger than it is. A good example may be seen at

Boat of Garten, Speyside, where there is very fine natural regeneration, which grew up under an open shelter-wood while the ground was being grazed by sheep.

Semi-systematic regeneration has been practised to a limited extent on the Seafeld property, but elsewhere little or nothing of this kind has been attempted.

Perhaps the most notable feature of these pine woods is the great devastation which has been done by the brown squirrel in the middle-aged and young stands. There are few plantations which are not damaged to a greater or less extent. The bark is torn off the stem in the region of the crown, and snow and wind complete the damage. Natural and planted pine and all types of trees are attacked, but there is evidence that the crown type of the indigenous race tends to make the damage less serious.

The most characteristic Scots pine area in England is on the Bagshot Sands, which form two basins, one in Surrey and one in Hampshire and Dorset. Unlike the region just described, this is a flat, gently rolling country. The ecological features of this type have been studied by Summerhayes, Cole, and Williams (29) at Oxshott Heath. They have defined two dry types, a *consociation* of *Calluna vulgaris* and a *community* of *Pteridium aquilium*, and two damp types, a pure *community* of *Molinia coerulea* and a mixed *community* of *Calluna*, *Molinia*, and *Erica tetralix*. The soil of the Bagshot Sands is generally a sand or gravel, but it is variable. Seams of clay impede the drainage in places, giving rise to the *Molinia* type, while in places the surface is overlaid with Plateau Gravel. Thus the soil types, although different in origin from those of the Scottish regions just described, have points of similarity with them. The rainfall is moderate, generally under thirty inches per annum, and exposure is rarely a limiting factor, except to the west of the region.

We can find no reliable data on the origin of the pines which are now so typical of the Bagshot Sands. The types appear to vary, some being good, while others have a coarse branching habit. Production is also variable in this region, principally correlated with pan formation, which is a feature of the *Calluna* moors, some of which are very poor, *Cladonia* spp. being a feature.

On the Bagshot Sands pine regenerates itself freely, although there has been no systematic natural regeneration. Summerhayes is studying the invasion of a felled area of this type. In places *Polyporus schweinitzii* and *Fomes annosus* are preventing the dominance of the pine, while the invasion and importance of birch (*Betula alba*, and in the wetter places *B. pubescens* also) is interesting when one recalls the history of the pine in this country.

A most important use of Scots pine in this country has been as a constituent of mixed woods. The Scots pine-larch mixture has already been noted, but this practice is not favoured to-day. Scots pine was used in this way with Norway spruce, and many of the relatively few spruce plantations which were formed were spruce-pine mixtures. In most cases the spruce outgrew the pine and formed pure or almost pure plantations. We have recently found that on certain sites this mixture is silviculturally sound, and this point will be referred to later.

Scots pine was more popular half a century ago than it is to-day, or was a century ago. On one hand its timber is inferior to larch, particularly in shorter rotations, while its volume production falls short of that of spruce. On the other hand it is less subject to heart-rot than any other of our coniferous species.

It is, however, the use of unsuitable strains and the damage from squirrels and pine beetle (*Myelophilus piniperda*) which have produced so many poor woods of this species. The pests mentioned, and also black game, which makes this species so difficult to establish in Scotland, must be more effectively dealt with than in the past if Scots pine is to occupy the place in our silviculture which our conditions and its merits justify. Of equal importance is the choice of the proper type of tree, and on this subject experience cries out that we should only propagate this species from trees of good silvicultural qualities of crown and stem, even though such types may be slower growing. There is no other species, with the possible exception of Corsican pine (*Pinus laricio* Poir.), which gives the same guarantee of success on the extensive tracts of *Calluna*-covered land which are to be found in so many parts of England and Scotland; for example, in addition to the tracts mentioned, there are the East Anglian Heaths, described by Farrow (11), some of which are being afforested by the Forestry Commission, and the moors of the Cleveland Hills, described by Elgee (6). On many of these tracts, particularly on the heavier soils, Scots pine may not be the permanent species, but its ability to grow on heather ground, and the ease with which it can generally be established, makes it an ideal pioneer species. It is worthy of attention that this species in natural forests was almost always associated with a broad-leaved species, generally birch. This appears necessary for the maintenance of favourable humus conditions, and birch or other broad-leaved species, such as beech, should be an auxiliary species in our pine plantations. Further, Scots pine has an important part to play in mixture, particularly with spruces, on our heather-grass moors, for example, in the Cheviots.

Corsican pine. The only other pine species which has had any importance in our forestry is Corsican pine. Owing to difficulties of nomenclature there is doubt about the introduction of this species, but according to Louden (18) and Elwes and Henry (7) it was introduced in 1759. A century ago its greater growth compared with Scots pine in the south of England was noted, but the oldest known plantation of the species is at Highclere, Berkshire, which dates from about 1837. This is a magnificent small plantation on a heather and bracken covered sand. When 80 years old it had attained a mean height of 104 feet, and an underbark quarter girth volume per acre of almost 10,000 cubic feet. As noted in the *Forestry Commission Bulletin*, No. 3, Corsican pine grows faster and gives higher volume production than the indigenous species, particularly in the south of England. One of the most interesting comparative plots was in Knightwood Enclosure in the New Forest, where at 52 years the mean height and volume of Corsican pine was 73 feet and 5,150 cubic feet respectively, compared with 57 feet and 3,085 cubic feet for Scots pine. Corsican pine has also been used successfully on maritime sand dunes, e.g. at Holkham in Norfolk and on the Culbin Sands of the Moray Firth coast. The general ecological features of the latter have been described by Stewart and Patton (28). There are two serious problems which make the future of this species doubtful in this country. They are the difficulty of establishing it and the quality of its timber. Its slow growth in early life makes it less suitable for direct sowing than its associate *Pinus pinaster*. As one would expect in a species which is native to a region which suffers from summer drought, its root is long and poorly branched from the beginning. Most of the lateral initials either do not grow out at all or only

to a very small extent, hence success in transplanting and planting is very dependent on the climatic conditions following these operations, with the result that heavy losses are frequent. Investigations now in progress on both these problems will make it easier to define the future of this species. Considerable damage has been done to Corsican pine at the higher elevations, particularly in North Wales, by *Brunchorstia destruens* Erikss.

European larch. It is remarkable how often fantastic futures have been prophesied for newly introduced forest trees, and in the eighteenth century the future of larch in this country was painted in very rosy colours. The qualities of its timbers were extolled, while a volume production of 47,600 cubic feet per acre at fifty years was estimated by Anderson (1) in 1796. Already the shadow was falling, and before the end of the century the stem *Chermes* (*Chermes viridis* Ratz, or *Chermes abietis* (L.), (Borner)) caused a scare, particularly in low-lying sites. In 1814 we find Sir Archibald Grant, quoted by Sinclair, referring to 'the great failure lately experienced in larch plantations'. Heart-rot, probably due to *Fomes annosus*, became prevalent about this time, even in very young trees, seven to eight years old. In view of the importance of this to-day, it is interesting to note that although it occurred on all soils, it was much more prevalent after a Scots pine crop. In recent years it has been found especially in the second crop of both natural and planted larch. It appears, therefore, that larch has always been liable to develop heart-rot in this country, and there is a danger in using it after any other coniferous crop. The greatest damage which this species has suffered is from larch canker. In the *Account of the Larch Plantations on the Estates of Atholl and Dunkeld* (2) it is stated that 'It has been found, that in soils which have been turned up by the plough, and which have borne white crops, the larch cankers. It cankers in wet situations also.' We cannot be certain that this refers to damage from *Dasyctypha*, but it cannot signify heart-rot, as this is dealt with immediately after. In other books of this period damage is described which is typical of larch canker. Although larch canker has almost certainly been with us for over a century, it does not seem to have been a serious disease, at least on the more typical larch sites, until more recent times. When we studied the larch on Craigvinean, Dunkeld, there was no evidence of canker damage in the timber, which showed healthy growth in early life, although the upper stem and branches were cankered. The wave of disease which caused such perturbation at the end of last and the beginning of this century was almost certainly the result of the misuse of the species. It was planted on low-lying sites subject to unseasonable frosts, on water-logged and heavy soils, and, above all, it was overcrowded in early life. Canker became increasingly abundant and attacked the species everywhere. It is recognized now that larch shows wonderful recovery from disease, particularly when given a chance by thinning. We know of plantations which at fifteen years seemed at the point of death, but which are now vigorous. To-day we see or hear little of larch canker, but this is rather the result of our having few plantations of the susceptible age, ten to twenty years, than to disappearance of the disease. The diseases of the larch have been fully dealt with by Hiley (15).

It is a mistake, however, to think that the story of the larch in this country is solely a pathological one. It has not been possible so far in this country to make a systematic study on the relation of seed provenience to silvicultural qualities because of the difficulty of obtaining data on origin of seed. Further, it is un-

safe to compare plantations of different ages, particularly in a species so subject to juvenile diseases. We can say, however, from considerable knowledge of larch plantations, particularly in Scotland, that many of the older plantations were remarkable for straightness of stem and good crown form, but there is considerable evidence that these features in this species are very dependent on external factors, particularly exposure to prevailing winds and density of stand.

The importance of site is the notable feature of our experience. The conclusions attributed to the fourth Duke of Atholl (2) have been confirmed by bitter experience. This species is typically a tree of middle and higher but sheltered slopes. It makes considerable demands on the fertility of the soil, while its relatively high rate of transpiration necessitates a continuous and moderate supply of water. The slopes round Dunkeld have shown themselves a second home of the species. Here we have morainic or *in situ* soils of mica schist and slate. The slopes of Craigvinian gladdened the forester's heart before the War, the larch, over 80 years old, being almost 100 feet high on the middle and lower slopes, while underneath were occasional old oaks. Even at an elevation of 1,000 feet a mean height of 80 feet was attained. This area has been replanted in part with larch, and we shall see if on this fertile site the timber is as sound in the second rotation as in the first. We know that the reverse is usually the case on the poorer and drier transported soils. A feature of the larch in this country has been its rapid growth and comparative health in regions of the west with high rainfall and an oceanic climate. One of the most notable examples was Braemore, near Ullapool, Western Ross-shire, where in 50 years heights up to 84 feet and underbark quarter girth volumes per acre of over 6,000 cubic feet were attained, the timber being sound and the canker damage not serious. Our experience of this species in this country has shown its sensitiveness to exposure to the prevailing wind. It is true that it has given good results at high elevations—for instance, up to 1,750 feet at Mar in Upper Deeside—but only with shelter.

There has been little natural regeneration of larch in Britain, the most notable example being at Toman Uird Wood, near Grantown, Speyside. Here there has been fairly complete regeneration, in places very dense, over a considerable area on a felled pine-larch site, the seed coming from an adjoining unfelled portion. The age is variable, but the oldest parts are now over thirty years. In places the crop is mixed with Scots pine naturally. The development and form of the larch is good, but an unfortunate feature is the incidence of heart-rot, due to *Fomes annosus*.

Larch undoubtedly requires early and heavy thinnings, not only to maintain its general health but also to keep its crown development vigorous. When once its crown becomes small, its response to thinning is feeble. This treatment means, however, that the tree crop does not utilize the light fully from a comparatively early age, as can be seen by the weed growth. Before the War, at Novar and elsewhere, interesting experiments were made with the underplanting of larch with such species as *Thuja plicata* (D. Don), *Tsuga heterophylla* (Sarg.), Douglas fir, Norway spruce, and Sitka spruce, with the idea on one hand of checking larch canker by cutting out most of the infected trees, and on the other of producing a crop consisting of saw-timber of larch and pitwood of the underplanted species. On the results to date this does not seem to be a promising line. In the first place, such excessively heavy thinning of larch is not

necessary to secure recovery from canker; periodic rather than one very heavy thinning is more beneficial. Further, the presence of the underplanted crop greatly decreases the flexibility in treatment until it can be utilized, i. e. for about twenty or more years. If heart-rot develops in the larch during that period, the crop cannot be felled without very serious damage to the underwood. The use of beech to keep the weeds down is more justifiable, particularly where they are of the type of bramble. However, it is doubtful if the use of beech as an underwood with larch is of such silvicultural value as with Scots pine which tends to form raw humus with its deleterious effect on the soil. A more promising line in larch silviculture appears to be the use of shade-bearing species in single-stem mixture with it. Scots pine, the only species used in single-stem mixture on any scale, is useless from this point of view, being a light-demanding tree; but *Thuja plicata*, *Tsuga heterophylla*, and spruces, now that we know that the *Chermes* danger would not be increased thereby, are worthy of trial.

Larch is the lowest volume-producing conifer we have, but the quality and value of its timber in all sizes more than compensate for this. This latter feature makes it valuable not only on typical larch sites, but also as a speculation on less suitable sites such as the loams and clay loams of the south of England.

Our century and a half's experience of this species has not confirmed the high hopes regarding it. Some of the disappointments were unavoidable, but many were due to gross silvicultural misuse. Provided this experience is utilized, we believe that larch has an important part to play in our future silviculture. The best results have been obtained on the more fertile sheep pastures on schistose rocks and shales such as the mica schists and the ordovician and silurian formations. Many pastures of this type are deteriorating for grazing owing to the continued increase of bracken, and their afforestation would provide ideal sites for larch. We believe that the principal use of this species in Britain is as a pioneer or first crop on the more fertile, elevated, but sheltered slopes.

Japanese larch. The only other species of this genus which has been used on any scale in this country is the Japanese larch, and this only since the beginning of the century. It is more vigorous in early life than the European species; and we have rarely seen cankers due to *Dasyctypha calycina* on it, although it has been subjected to the rigorous test of admixture with European larch. Japanese larch sometimes does not have straight stems, but exhibits the phenomenon of wavy growth. Its timber appears less strong, durable, and probably more brittle than that of European larch, but perhaps not when similar rates of growth are compared. But for one characteristic, namely, the fall-off in the rate of height increment after early life, which takes place both in Japan and in groups of older trees in this country, this species would be a serious rival to the European species in this country. Until we have longer experience of it in plantations, and greater knowledge of the qualities of its timber, it would be unwise to use it on a large scale for timber production. It has one quality which should be utilized; it grows well on raw humus and breaks it down. This was claimed for the European larch on introduction also, probably with justification before its vigour in early life was impaired by disease. Japanese larch, therefore, has an immediate place as a pioneer and probably temporary crop on some raw humus types, particularly on the west coast.

Norway spruce. It is remarkable that this species, which has played a notable part in forestry in continental Europe, has been so unimportant in this coun-

try, particularly as it was one of our earliest introduced conifers. Walker (31) states that it was first planted in Scotland as an ornamental tree at Inverary in 1682, but it was not used in plantations until later. He deplores its use on dry ground and states that it requires moist conditions. The fourth Duke of Atholl (2) used it to a limited extent in the moister places in his larch plantations more than a century ago, and Loudon (18) records its use on peat on the Pentland Hills by a Duke of Argyll in the eighteenth century. Few plantations of any size were formed then or until recent years. When planted, it was frequently mixed with Scots pine, and this, rather than heavy thinnings, explains certain features of our Yield Tables (see *Forestry Commission Bulletin*, No. 3), such as number of trees per acre, which differs from continental experience. A number of successful plantations at the higher elevations in Cumberland, Wales, and Aberdeenshire, quoted in *Bulletin* No. 3, the generally high volume production, and especially the afforestation of the wetter moorlands for which other species appeared unsuitable, have resulted in the more extensive use of Norway and Sitka spruces since the War, particularly by the Forestry Commission.

It is well known that even on favourable sites a number of years elapse before Norway spruce begins to grow vigorously. On peat and moorland soils generally—particularly where *Calluna* is an important herbage plant—the slow growth of this period is accentuated and prolonged, the needles become short and yellow and growth almost ceases. Frequently after a period of years patches come away, while the plants alongside are still in a state of check. This emergence from check is correlated in a general way with the species forming the surface herbage. In some cases a second period of checked growth may follow after one of fair development. The writer has studied the silvicultural aspect of this problem during the past five years, and the following is an outline of the conclusions of this unpublished investigation. When planted in the ordinary way on soils which are well aerated, the spruce roots which have developed in the nursery continue to grow and some bend up into the surface layers; but on peat, clay, or other poorly aerated soils the nursery roots show little further development, especially when the vertical notch-planting method is used, and the roots inserted into the deeper and more poorly aerated layers of soil. On all soils, however, the principal part of the adult root system is that developed adventitiously from the collar of the root. In some cases this begins to develop immediately after planting, while sometimes years elapse. On normal soils vigorous growth does not begin until this secondary system is functioning. On the poorly aerated soils delay in development, combined with the feeble growth of the initial system, leads to a condition of severe check to growth. Correlation between the development of the adventitious system and emergence from check has been found, but the development of this later-formed system does not necessarily lead to shoot growth. Normally these adventitious roots run in the superficial layers of soil and humus and bear bunches of mycorrhiza rootlets in the humus layers. Under conditions of poor aeration such as is typical of moorland conditions these roots are even more superficial, and when they run through relatively decomposed plant remains or *Calluna* humus they remain bare pioneer roots and may attain great lengths—for example, 13 feet in 12 years after planting has been found in the case of Sitka spruce. When the roots are of this type check conditions continue. In the decomposed remains of certain plants—particularly grasses, including the moorland species *Molinia*

coerulea, but even in decayed *Sphagnum*—bunches of mycorrhiza rootlets are formed, and this leads to the emergence from check if they continue to function. In some instances with the continued luxuriant growth of peat-forming plants, such as *Sphagnum* and *Polytrichum* species, they may die and a whorl of adventitious roots may be found higher up the stem. If these latter remain of the bare pioneer type a second period of check follows. Even on the basis of this incomplete knowledge we see that the state of check may be caused and may continue from different causes. The initial check can be mitigated by planting methods, e.g. turf planting, which increases the conditions of aeration for the nursery root system. This only leads to a temporary improvement unless the surface herbage species and their humus condition are favourable, because the adventitious and other roots rapidly leave the turfs. On the other hand vertical notching, particularly with screening (i.e. the removal of the turf), gives unsatisfactory results. The exposure of the peat, when present, causes it to shrink, water collects, and the conditions of aeration become worse. Further, the herbage conditions are not static; important changes, particularly in relative dominance, take place when grazed land is enclosed and drained, and when periodic burning ceases; and on the above hypothesis the nature of these changes is of great importance in determining the success or failure in establishing spruce. For example, if there is luxuriant growth of *Sphagnum* and *Polytrichum* species and this is not checked by drainage, then the conditions favour the development of the bare pioneer type of root and check is likely to continue. Again, we have a great extent of *Calluna-Molinia* pasture, with associated plants, on the Cheviots and elsewhere. This pasture is grazed by sheep both in summer and winter, the *Molinia* forming the summer food, the heather the winter, and *Eriophorum vaginatum*, when present, the spring food. The effect of grazing on the *Calluna* is pronounced and it is often dwarf and inconspicuous. When enclosed and planted it tends to become dominant, and in view of the deleterious effect of its humus on the development of the spruce root system, the conditions gradually become less favourable for emergence from check. If, however, *Molinia* is abundant, on enclosure and drainage it tends to become more luxuriant and to smother other species. The site then becomes more favourable for the root development of the spruce, although *Molinia* tends to cover up the trees also, and there is danger from unseasonable frosts on grass moors. For spruces, the surface herbage not only indicates the suitability for the species, but it appears to be necessary, directly or indirectly, in the nutrition of the trees until canopy closes and the trees form their own humus. The role of spruce as a pioneer species is therefore a limited one. We believe that it should only be planted where grasses are present and only pure when they are abundant. *Calluna* is a difficult species to get rid of, and when present is likely to increase in dominance. The most helpful line on *Calluna-Molinia* herbage is the use of Scots pine in mixture with the spruce. The pine generally comes away, keeps down the *Calluna*, and forms humus conditions favourable for the development of bunches of mycorrhiza rootlets on the adventitious roots of the spruce, which later come away. Examples of this were recently seen in the Cheviots. In all cases Scots pine may not be the most suitable pine.

Sitka spruce. In this country our experience of this species in plantations is comparatively recent and not extensive. The oldest plantations are at Strathgyle, Deeside, and these unfortunately were seriously damaged in the gale of

January 1927. They are very interesting, for unlike most plantations of recently introduced exotics they are not growing on a favourable site but on peat in an exposed situation. In 43 years a mean height of almost 70 feet has been reached, and the volume production is 7,500 cubic feet per acre (true measurement underbark). Further, the Sitka spruce has suppressed the Norway spruce when in mixture with it. At Drumlandrig, Dumfriesshire, Sitka spruce has been used in plantations for the past thirty years and shows very good growth. A sample plot gives for an age of 26 years a mean height of 58 feet, and a true volume underbark of 5,895 cubic feet. At Dunach, Argyllshire; Haggerston, Northumberland; Highclere, Berkshire; and elsewhere, there are small, flourishing plantations twenty years old or more. There are also many promising younger plantations; and in almost all cases when comparison with Norway spruce is possible, the Sitka spruce is more vigorous than the European species, perhaps particularly so on *Molinia*-covered moorland, such as at Muirburnhead, Dumfriesshire. Its only serious enemies until now have been *Aphis abietina*, which causes defoliation, and *Armillaria mellea*, which sometimes does serious damage on sites which previously carried hardwoods. It is therefore not to be wondered at that Sitka spruce is now being used extensively even though our experience of it is limited. We do not yet know its specific requirements—which indeed appear similar, if not identical, to those of Norway spruce—but its greater vigour will probably enable it to succeed under more adverse conditions, for example, of exposure. Its root development in early life is the same as that of Norway spruce except that it is more vigorous. The notable feature of Sitka spruce is that it brings hope to our more difficult sites, and it is for these that we require an enrichment of our coniferous flora.

Douglas fir. Although we have more experience of this species than of any other of the more recently introduced conifers, our knowledge of its place in our silviculture is far from complete. Practically all the older and most of our younger plantations are on favourable sites as regards soil and shelter, and on such Douglas fir has shown phenomenal height growth. For example, at Taymount, Perthshire, at 65 years a mean height of 105 feet has been attained, and at Tortsworth, Gloucestershire, 112 feet in 55 years. Even at Balmoral, Aberdeenshire, at an elevation of 1,000 feet, but sheltered, a mean height of 72 feet was attained in 43 years. The volume production of the species has not been remarkable relative to height growth, the corresponding underbark volumes per acre being at Taymount 9,595 cubic feet; at Tortsworth 10,390 cubic feet; and at Balmoral 7,830 cubic feet. This is due principally to taper, but in some cases at least the tree may become more cylindrical with increasing age. Many of our earlier plantations were originally mixed; for example, Taymount was a larch-Douglas fir mixture. In most instances the Douglas fir rapidly outgrew the other species and the plantations were therefore open in early life. At the beginning of this century the tendency was in the other direction, and Douglas fir was usually planted at three to four feet apart. At such spacings the rapid growth quickly overcrowds both the crowns and roots of the species. The centre of gravity of the crown rises, and this, together with subnormal root development in relation to height, makes the plantations unstable to wind and snow.

Further, this species unfortunately suffers from root- and heart-rot, due in some cases, if not all, to *Fomes annosus*. Many young plantations under twenty years, particularly on transported soils in Scotland, are showing signs of the

beginning of heart-rot, and this still further affects the stability of the plantations. It is very difficult to thin overcrowded woods of this species without windfall, and it is even more dangerous to leave them untended. Another defect of the species, particularly in Scotland, is the low percentage of straight stems in the young stands. Our experience indicates that to keep plantations wind-firm and to avoid snow damage, initial spacings of the order of six feet together with early and heavy thinnings are necessary. The thinning experiments being carried out by the Forestry Commission have not been in progress for a sufficiently long time to indicate the best type of thinning, but the correction of bad stem form is more easily done in a crown thinning (D grade), provided it is applied early enough.

This species has not yet been planted under a sufficient range of conditions to enable its site requirements to be defined. We know, however, that it is unsuited for exposed situations, where it suffers from severe deformation. Its most luxuriant growth is under favourable conditions of soil and shelter, and the greatest field for its use in the immediate future appears to be on the less heavy soils in the south of England which have carried poor hardwood crops. We have examples, however, of successful young plantations on the poorer soils, e.g. sands and gravels, and it may be that the species has a greater future in this country than we believe at present.

The timber of Douglas fir grown in this country is not viewed with favour by timber merchants. This appears to be due to the age of the trees utilized, and to a less extent to physical characteristics. No coniferous species gives its best timber on short rotations, and particularly so when growth is very rapid. It is true that the rings are wide and the wood often spongy; while when the trees are not straight its use for pitwood is impaired. On the other hand the timber is relatively durable and it can be produced in large sizes. When the timber of Douglas fir has been studied in more detail it will be the task of silviculture to see how far its defects can be remedied.

Owing to lack of stability in young plantations, the liability to heart-rot under certain conditions, and to timber difficulties, Douglas fir is less popular in this country than in the immediate past. But it has obvious qualities, and we have large areas—particularly in England—for which it is suitable, and still larger areas for which it may be a valuable species; hence we believe that it will have an important place in our future silviculture.

These observations refer to the green or coast form of Douglas fir. The blue (*glauca*) form does not appear to have any place in our silviculture, because it grows very slowly and has no special qualities. The *caesia* variety is attractive silviculturally because of its more 'spruce'-like and compact form of branching; while its slightly slower growth compared with the coast form may make for greater stability and better timber. Unfortunately its earlier flushing renders it more liable to frost damage in the spring; while *Rhabdochloa pseudotsugae* and *Chermes cooleyi* appear to be more serious potential enemies of this form, although both occur on the coast type also.

There are a considerable number of other coniferous species which have been or are being used to a limited extent in this country. *Pinus pinaster* and *P. radiata* (D. Don) are being established, principally by direct sowing, in some pine areas in the south and east of England, while it is considered that *Pinus contorta murrayana* (Engelm) may have a place on moorland soils, perhaps in mixture with spruces. *Pinus strobus* (L.) is rarely used because of the 'blister'

disease. Silver fir (*Abies pectinata*, DC.) is no longer planted owing to the serious effects on it of *Dreyfusia nüsslini* (Borner). What appeared to be damage from a *Chermes* species was described in 1839 by Miller (20) and Balton (3), and *D. nüsslini* has been a serious pest in recent times. *Abies grandis* (Lindl.) has shown remarkable growth, particularly at Novar, Ross-shire, but it is developing heart-rot there. *Abies nobilis* (Lindl.) has been used to a limited extent and grows well, e.g. at Poltalloch, Argyllshire. There is a number of small plantations of *Thuya plicata* and *Tsuga heterophylla* in different parts of the country and in general the species grow well. *Keithia thuyae* does damage to Thuya, particularly in the nursery stage, and root diseases are a danger, but otherwise these species are healthy, and both merit a more extensive experimental use, especially in mixture with larch. If it were not for the tendency to fork, *Cupressus lawsoniana* (Murr.) would be quite a promising tree in the south, while *C. macrocarpa* (Hartw.) may have a future even on poor soils in the south of England.

To-day we are witnessing a considerable extension of our coniferous woods, partly by private owners and partly by the Forestry Commission. As in the past, planting is the method employed, direct sowing being comparatively rare. This is not to be wondered at, because on the more fertile sites the weed growth on non-forest land or devastated woodland is a serious obstacle to direct sowing, while on the poorer sites leached and unfertile surface layers prevent that rapid juvenile growth which is so essential in direct sowing. The notable feature in our planting is the widespread use of transplant as distinct from seedling stock. Both types of stock have been used extensively in the past, but to-day the balance is definitely in favour of the transplant. This is probably necessary, particularly on land which has not previously carried a forest crop with complete canopy. The weed growth, rabbits, and danger from drought, which are characteristics of our sites, make a well-balanced and fairly large plant necessary for planting. The present tendency is away from large stock, i.e. over two feet, and we may see in the immediate future the more extensive use of seedlings on certain sites which do not suffer from heavy weed growth.

As in the past, notching is the principal method of planting, but the simple vertical notch is now commoner than the more elaborate ones such as the T-notch. These latter types adapted to shallow planting should be more widely used for spruces. The mattock is used largely also, and this tool has obvious advantages on the more consolidated types of soil.

We are fortunate in this country in having so many coniferous species which grow well with us, and we have the advantage to-day of all the pioneer work which has been done by private owners during the past century and a half in the use of exotic species. All exotics on all sites are not successful, and no species is without defects. The successes and the failures which we have had, however, equip us more adequately for the extension of our coniferous forest than at any time in the past. The great problem which faces us to-day is the afforestation of peat sites including certain types of *Calluna* moor. Many of the greatest tracts of potential forest land in this country exhibit this problem in some form or other.

In a country such as Britain, where forestry is on an artificial basis, there is much greater need of intensive research than in one where natural regeneration and indigenous species are used. In the latter case, ecological research is usually very fruitful; but we require something more, namely, much more complete

knowledge of the soil in all its complexity, not only within the forest but during the transition to forest. Equally important is greater knowledge of the physiology of trees. Many of the most important tree diseases cannot be adequately dealt with until the normal physiology of the host is known. The present distribution of trees is too accidental to justify the sole use of indigenous species unless the native flora is very rich; hence we consider that silviculture is not fully developed until a full range of species suitable to a region is employed. This more artificial type of forestry must, however, be founded on greater knowledge of soils and the life processes of trees, and the obtaining of this knowledge should be the task of this century. The subjects are very complex and difficult, but the fruits to be gathered are very great.

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SILVICULTURE OF HARDWOODS IN GREAT BRITAIN

BY W. H. GUILLEBAUD

INTRODUCTORY.

THE most widely distributed and important of the British hardwoods are oak (*Quercus pedunculata* and *Q. sessiliflora*), beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*), elm (*Ulmus campestris* and *U. montana*), and birch (*Betula pubescens* and *B. verrucosa*). Of lesser importance are sycamore, alder, Spanish chestnut, and poplar.

The total area in Britain under hardwoods, excluding scrub but including mixed woods in which hardwoods probably form the greater part of the crop, is approximately double that under conifers. The conifers occupy mainly the higher ground in the west and north, and the hardwoods the low-lying ground in the south and east of the country. In Scotland hardwoods form a much smaller proportion of the total area of woodland than in England, and growth is generally poorer.

In the main the hardwoods occur on the heavier loams and clays, as well as on calcareous hill ranges in the south of England, such as the Downs, Chilterns, and Cotswolds. There are certain parts of the country, such as the Thetford district of East Anglia, where hardwoods, usually in mixture with conifers, occur on sandy soils. The hardwoods have been grown in Britain under all of the three main forestry systems, High Forest, Coppice-with-Standards, and Coppice, although the relative area under each system varies very much with the individual species. Coppice-with-Standards and Coppice occupy proportionately a larger area in the south of England than in the north or in Scotland.

In England, apart from the heaths and chalk downs, hardwoods probably covered the greater part of the non-mountainous part of the country in Roman times. With increasing population the forest area rapidly diminished, and towards the end of the Stuart kings this process was accelerated by the demand for wood for smelting iron in certain districts, notably Kent, Surrey, and Sussex. According to Forbes,¹ prior to the Restoration practically all the woods in England were of the Coppice-with-Standards type, and only with the beginning of the seventeenth century was any serious attempt made to establish oak on new ground in the form of ordinary plantations. Later on, in the latter half of the eighteenth century, the passing of the Enclosure Acts led to a great development of forestry, and it is during the period 1750 to 1820 that the bulk of the larger plantations on English estates were established.

Usually the heaviest land was selected for hardwood planting, especially land which was unfit for agriculture either by virtue of its configuration (streams and gullies) or because for some other reason it was difficult to work. The woods which occur massed round the parks and mansions belonging to large estates were formed, no doubt, partly for scenic purposes, game cover, &c., and partly to provide timber for estate requirements. The areas so planted were for the most part relatively small; thus it is exceptional to find woods of over 500 to 1,000 acres in extent planted by private enterprise, the majority, indeed, of the individual hardwood plantations in this country probably not exceeding 100 acres. The largest areas are those now belonging to the State, such as the

¹ A. C. Forbes, *English Estate Forestry*, pp. 11-13.

Forest of Dean and the New Forest, most of which, 120 years ago, were in a more or less completely derelict condition; about that time large tracts of the Forest of Dean and other small Crown Forests in the Midlands and South of England were enclosed, cleared of the remnants of the old crop, and replanted with oak, often with conifer nurses, the bulk of which remains to the present day. Outside the Crown Forests very little pure oak was planted, and nearly all the woods existing now (excluding beechwoods and coppice-with-standards) are mixed woods. The mixture most favoured was, until quite recent years, what might be called the 'portmanteau' type, i.e. it included so many species that the puzzle is often to find what had been omitted. The staple hardwoods of course were there, oak, ash, elm, sycamore, Spanish chestnut, occasionally beech, lime, cherry, &c., and along with these, usually, were planted larch, Scots pine, and spruce. The conifers were planted as nurses for the hardwoods and were sometimes all removed in the thinnings before the wood reached middle age, though often a proportion was left to grow on to maturity.

The present distribution of age classes in the hardwoods in this country is a serious feature in British forestry. An overwhelming proportion of the woods are mature or overmature, while the area replanted with hardwoods during the last twenty years is vanishingly small. This state of affairs calls for drastic action if the proper balance is to be restored, although there are many difficulties in the way, for some of which British silviculture has been in no small degree responsible.

OAK HIGH FOREST.

There are few more depressing spectacles to the forester than the average mature stand of oak in this country. Such a stand represents the results of 100 to 150 years of growth, and in it can be clearly read much of the treatment to which our woods have been subjected in the past. Instead of serried ranks of tall clean boles with symmetrical luxuriant crowns, the observer sees a thin, straggling crop, short boled, with irregular crowns, the lower branches mostly dead and remaining as ugly snags from which disease and rot too often pass downwards into the bole; the ground below is commonly a riot of bramble and thorn, and the production not one-fifth of the total which the land is capable of carrying. The explanation may be summed up in a single word, over-thinning. The woods have been drastically opened out, starting from the small pole stage, at about twenty-five to thirty years of age, or even sooner, and the process steadily continued until the number of trees was reduced from twenty to fifty per acre, at which point the limit was usually reached. For perhaps thirty years or more many of these woods have remained in this state, the crowns have developed steadily, if irregularly, and, with the establishment of canopy, height growth has been renewed and suppression of the lower branches brought about. The extra length of bole so produced is useless as timber, and a grave menace to the health of the tree.

The causes which led to this widespread practice of heavy early thinning have probably varied from district to district, but the main factors are believed to be as follows:

In the first place, the treatment of our high forest areas has been largely a legacy from the coppice-with-standards woods, which, until 200 to 300 years ago, comprised practically the whole of our English forests. With the increasing

demand for bent and kneed oak for shipbuilding, and the recognition of the fact that coppice-grown oak could not be surpassed for the purpose, it was natural that the silvicultural methods learnt from the coppices should be applied to the new plantations in which coppice was lacking. Further, the demand for oak bark made thinning a very profitable practice, and thus the tendency was to reduce the number of trees per acre to quite a low figure comparatively early in the life of the plantation. Then again, the introduction of the conifer nurse is an important factor which has contributed to the open state of many of our hardwood areas. Larch, and sometimes Scots pine and spruce, were often planted along with oak as nurses; the original proportion of the hardwood was not infrequently low, and this was further reduced by suppression, when, as was commonly the case, the conifer greatly outgrew the oak, and also by the invasion of rabbits, which spared the thicker-barked larch or Scots pine but girdled many of the young hardwoods. The thinning out of the conifers for revenue invariably left the wood in an open state.

Another predisposing cause leading to early and heavy thinning has been the game question. Dense young plantations, with merely a dead leafy layer over the soil, however admirable they may be from the purely silvicultural point of view, are not welcomed by the gamekeeper, and the latter's influence has always been directed towards early opening out of the canopy to produce a certain amount of undergrowth of bramble and shrubs for game cover.

Except in semi-natural woods on calcareous soils it is exceptional to find any admixture of beech in the older oak stands; hence the rank weed growth and apparently inactive soils of so many of these woods.

Apart, however, from over-thinning and lack of beech or other shade-bearers, there can be little doubt that the defoliation caused by the frequent attacks of the oak-leaf roller-moth within recent years has increased the growth of rank vegetation under the oak.

The state of our oak high forest crops would be unsatisfactory enough if the majority of the older woods were healthy, but this is unhappily far from being the case. Over a large part of southern England the oak has visibly deteriorated within the past ten years. Following a series of severe tortrix attacks, there has been widespread die-back of the oak, necessitating much premature felling. This is particularly serious owing to the bad market at present for British oak. We are not alone in this country in suffering from a sudden dying back of oak; the same has been reported recently from Germany, France, and Slavonia, also following severe defoliation by various caterpillars. There is reason to believe that the *coup de grâce* is often given by *Armillaria mellea*.

A study of the height growth of our older oak stands would undoubtedly give us much useful information, but, so far as the writer knows, little work has yet been done in this direction. Some data collected in the Forest of Dean and Windsor Forest are of interest. For the first twenty-five to thirty years of the growth the age-height curve follows closely the trend of the curve given by Schlich in his *Manual of Forestry* and based on German data; from that point, however, the two curves diverge widely, the German curve continuing upwards and falling off relatively gradually, the English curve flattening out abruptly and so continuing to the end. The Forest of Dean records indicate that heavy thinnings started when the woods were about thirty years old, the conifer nurses being then removed, and there can be little doubt that these thinnings, which con-

tinued over a long period, were the cause of the abrupt, abnormal fall-off in the height growth.

The proportion of high-forest oak in the younger age classes is very small, and apart from the activities of the Forestry Commission there seems to be little prospect of any improvement in the position in the near future. Of those young woods which do exist many are the result of the conversion of oak coppice or coppice-with-standards to high forest—incidentally, some of these converted stands are very promising—and in the bulk of the remainder the oak is in mixture with conifers and unlikely to produce first-class timber.

As regards the restocking of oak areas, the first problem with which the foresters are faced is not so much how to regenerate oak as the conditions under which it should be regenerated. There is so much inferior oak throughout the country growing on apparently good oak soils that we really do not know with any assurance whether a given soil now carrying oak is fit to carry oak again or not. The expression 'oak sick' is commonly heard in connexion with these soils, but whether the present inferior crop of oak is due to bad silvicultural treatment, or to water stagnation, the old drains having been allowed to fill up, or to water shortage—for example, there has been a general lowering of the water table in the London Basin and in the Forest of Dean—or to the Oak Tortrix and Oak Mildew attacks, or to any or all of these factors in combination, no one at present is able to say. The whole position is extremely obscure and badly in need of investigation. Broadly speaking, the present tendency is to convert the oak woods on the lighter soils to conifers, from which a much higher and earlier return is anticipated. Some of the heaviest clays are being brought under poplar and even under spruce, while such attempts as have been made to re-establish oak on the better clays have proved very expensive and not particularly successful. It is by no means certain that it is necessary from the silvicultural point of view to convert oak on the lighter soils to conifers, particularly on such formations as the Old Red Sandstone in the West of England; these soils generally contain a considerable proportion of clay particles, the weed growth is not so heavy as on the stiffer clays of the lowlands, and, so far as can be judged, the growth of the oak is usually better.

Much doubt also exists as to the relative merits of pedunculate and sessile oak. The existing oak woods on the heavier soil are mainly either pedunculate or one of the many intermediate forms between the two species, but sessile oak is the commoner species on the shallow soils of the non-calcareous hills of the North and West of England. It is also an indigenous species on certain sandy formations, such as the Hastings Beds of the Weald in the South of England.¹ The natural distribution of *Q. sessiliflora* is thus confined mainly to non-calcareous and often sandy soils, but there is some evidence for the belief that even on stiff clay soils *sessiliflora* may be the more profitable tree. It is usually a taller, cleaner grower than pedunculate oak and is much less subject to defoliation by Tortrix. The timber is also easier to work, although some timber merchants dislike it on the ground of a supposed tendency to split after felling. Until quite recently little attempt has been made to raise stocks of definitely sessile origin. In future, when acorns are being collected, it is of great importance to keep the two species separate, marking sessile oaks when in leaf, and collecting only from marked trees.

¹ Moss, 'British Oaks', *Journal of Botany*, vol. xlviii, 1910.

The rarity of full mast years and heavy weed growth over the soil are often held responsible for the failure of most attempts at natural regeneration of oak in this country, but Watt¹ has shown that biotic agencies (rabbits, rodents, insects, &c.) are primarily responsible. It would seem that many of our difficulties may be traced back to the disturbance of nature's equilibrium due to game preservation and the consequent destruction of all so-called vermin. Watt also suggests that the main value of the ancient practice of pannage—driving swine into the forest—lay not so much in the disturbance of the ground and burying of the seed as in the destruction of slugs and other harmful creatures.

Apart from a few blocks in the State forests, there has been no large-scale successful natural regeneration of oak in this country, and such re-establishment as has taken place has been mostly by means of either sowing or planting. Direct sowing has not proved a great success so far, and there is abundant evidence to show that for this biotic agencies are mainly responsible; thus what has been accomplished in recent years has been mainly by means of planting. In planting oak the tendency has been to follow much the same lines as in conifer planting, namely, to use fairly small plants spaced at 4 to 4½ feet apart and either pure or with 50 per cent. mixture of larch, or at about 15 feet apart in a matrix of several species of conifers and hardwoods. When oak is planted pure in this way on weedy land there ensues a prolonged struggle with the weeds, and the young plants often sit still obstinately for a number of years—up to ten years in many cases—with the result that by the time the plantation is properly established a small fortune has been spent on weeding. There are two ways out of the difficulty; one is to use larger plants, but these are costly to raise in the nursery and there is constant trouble with oak mildew; the other is to plant the young trees much closer together, i.e. at 3 ft. by 2 ft. or 4 ft. by 1 ft., using one-year or two-year seedlings, and either to keep the weeds down by hoeing or by cutting so frequently that the plants are always clear. It is a matter of common observation that by crowding oak in the young stage it can be made to come away, and close planting is undoubtedly the best way to succeed. Unfortunately the private owner cannot afford to plant extensive areas in this manner, and even the Forestry Commission is strictly limited in its funds, so the prospect of raising oak in quantity is poor. For national reasons it is hoped that the Commission may be able to find the necessary funds for a reasonable acreage of oak plantation irrespective of the high cost of formation. It by no means necessarily follows that the financial results will be bad. It seems certain that the country will be denuded of good oak within a comparatively short time, and the price of oak timber 100 years hence is almost bound to be in closer connexion with the costs of production than it is at present.

The right stage at which to thin and the necessity for introducing beech are problems for the future to decide, though with regard to the latter point there can be little doubt that beech will be required on almost every type of soil.

BEECH HIGH FOREST.

In the past beech has played a comparatively small part in British forestry. The only extensive areas are on the chalk and limestone ranges of eastern and southern England, while it is rarely found in mixture with oak and ash on the

¹ A. S. Watt, 'On the Causes of Failure of Natural Regeneration in British Oakwoods', *Journal of Ecology*, vol. vii, 1919.

heavier soils in the lowlands. As Forbes points out in his *English Estate Forestry*,¹ the shade-bearing character of the beech has militated against its use in our small British woodlands, where ground cover for game is such an important factor.

In the Chiltern Hills, however, beech comes into its own as a tree of first importance. The chair-making industry centred round High Wycombe at first obtained all its supplies of beech timber from the Chilterns, but as the industry developed the local woods were unable to supply the demand, and now the greater part of the timber used in the factories is imported from abroad. Unfortunately one result of the large demand has been practically to denude the woods of big timber, and at the present time most of the stands are under sixty years of age. The woods are worked on a form of selection system, fellings being made at irregular intervals, in which all merchantable trees are removed. The gaps so formed seed themselves from the surrounding younger trees and an uneven-aged stand results. The success of the method depends largely on the frequency with which fellings are made, the stock of rabbits, and the type of trees left as seed-bearers. When too much is cut at one time and no mast year follows, brambles tend to get the upper hand, and with the steady depletion of the growing stock a very unsatisfactory position arises. The practice on some estates has been to cut all the best trees each time, leaving the forked misshapen stems to reproduce the new crop. This treatment is termed by the Danish foresters 'Negative Selection', and is disastrous for the future of the woods.

On the whole, natural regeneration is good in the Chilterns, especially following a full mast year. Watt,² who has studied in detail the factors which influence the regeneration of beech, came to the conclusion that successful regeneration can be obtained by keeping beech stands dense until a full mast year occurs and then making a fairly heavy utilization felling. Seedlings not only spring up in abundance in gaps of fair size but continue to grow, while those which appear under the shade of the mother tree quickly disappear, from a variety of causes, of which animal and insect attacks are the most important.

A curious feature noted by W. P. Greenfield³ is the absence of beech regeneration on the Lincolnshire Wolds, and also in Norfolk and Yorkshire. In that part of the country the soils are mostly glacial and subject to spring drought. Seedlings only appear following exceptionally wet seasons.

Of recent years the value of beech as a soil-preserving species, in mixture with light-demanding hardwoods and conifers, has been generally recognized, but the depredations of rabbits and mice have wrecked many promising plantations. The small size of the woodlands on most estates, and the heavy stock of rabbits usually permitted, make it essential to exclude rabbits from plantations containing beech for at least twenty years. This has not been recognized in general practice, and with the decay of the enclosing netting the plantation is usually expected to look after itself. The common result is the speedy disappearance of the beech from the mixture. The experience of the Forestry Commission, gained from the afforestation of large rabbit-infested areas in the eastern counties of England and elsewhere, has been that by intensive measures of control over large areas rabbits can be completely wiped out and that fencing

¹ Forbes, loc. cit., pp. 74-80.

² A. S. Watt, 'Ecology of British Woods', *Journal of Ecology*, vol. xi, 1923.

'Beech in the Lincolnshire Wolds', *Quarterly Journal of Forestry*, vol. xiii.

can be dispensed with once the land is properly cleared. This applies only to blocks of several thousand acres.

MIXED HARDWOOD CROPS IN HIGH FOREST.

If the areas under pure beech be excluded, the greater part of the hardwood areas in this country grown under high forest are mixed. These mixed woods form the characteristic type of woodland in and around the great parks on large estates, and, as in the case of oak, the preponderance of the oldest age classes is very marked. Many of the woods are unquestionably over-mature and almost all are greatly understocked, having served for many years as a reserve on which to draw as occasion arose to meet estate requirements, but owners are loth to clear fell for sentimental reasons, apart altogether from the sporting value of these open woods. Further, difficulties often arise over marketing mixed woods, containing as they do a large variety of trees; much lower prices are usually realized for mixed parcels than could be obtained from a timber merchant for a block containing one or at the most two species.

A good deal of natural regeneration, especially of ash and sycamore, often springs up in the larger gaps in mixed woods, and much more systematic use might be made of such groups than is normally the case. The principal obstacle to successful regeneration is the presence of rabbits and other vermin.

The problems which confront the owner of these mature mixed woods, when felling is ultimately decided on, are similar in most respects to those discussed in the previous section dealing with oak, and the majority of the land inevitably goes back to the easily and cheaply raised conifer plantation.

The younger mixed woods are often well stocked and the object of much patient tending on the part of the foresters concerned. The difficulties involved, however, are very considerable; not the least of these is the difference in the rates of growth of the various species in a typical 'portmanteau' mixture. It is not uncommon, for instance, to see a young mixed wood containing both hardwoods and conifers with the hardwoods badly sandwiched by the faster-growing larch or other conifers. In such a case the forester is in a dilemma: if the larch is left in, the crop will speedily revert to pure conifer, while the result of its removal may be to deprive the crop of its only really thriving trees for the sake of a medley of straggly hardwoods, the future of which appears distinctly uncertain. The happy mean is easier to attain in theory than in practice.

Another problem which these mixed woods present is that of obtaining a sufficient number of hardwood stems of good type for the final crop; the larger the number of species in a mixture the less easy is it to control the distribution of the species desired and to eliminate defective trees in the chosen species.

The present trend of forestry opinion in this country has been emphatically against these complicated mixtures and towards either pure crops or mixtures containing not more than two or at the most three species.

In the following notes brief mention is made of the main broad-leaved species entering into the composition of mixed hardwoods apart from oak and beech.

Ash. The common ash occurs naturally on calcareous soils and is an almost universal component of our mixed woods. It is very rarely grown pure and thrives best on deep, moist calcareous soils in mixture with oak and beech. Watt has shown that ash is unable to stand severe exposure, and in all exposed sites requires the shelter of beech for its successful development.

Ash is a difficult tree to raise on the heavier soils, as the young plants often make scarcely any growth for a number of years; when planted with larch, it is only when the branches of the latter have nearly met that the ash may begin to put on good shoots. Ash is notoriously frost tender, and repeated frosting during the late spring and summer is an important factor in checking the growth in early years, for which reason it is grateful for partial overhead shelter until the tops are above the frost level.

Ash regenerates freely in small openings cut in the old crop, except when rabbits are numerous, and forms dense groups even under partial shade. Such groups require careful handling; if freed too suddenly growth may check badly, while caution is needed in thinning, as the young stems often are too slender to stand any abrupt increase in growing space. As ash is difficult to raise by planting, all natural groups should be carefully preserved.

Elm. Two species of elm, *Ulmus campestris* and *U. montana*, with their numerous varieties, are widely distributed in Britain, and frequently occur in mixed plantations, although never planted as a pure crop. More characteristic, however, of elm in this country is its use as a hedgerow tree, especially in the South of England, where it forms the most prominent feature of the landscape.

The common elm is usually raised from suckers or layers, as the seed does not ripen in Britain, but the wych or mountain elm seeds freely and is easily grown.

Sycamore. This species is similar to ash and elm in that it has seldom been planted pure; occasionally groups may be found, but very rarely blocks of any size.

Of late years the demand for well-grown sycamore boles has increased considerably and clean butts can always command a good price. It is a hardy tree and very resistant to exposure, besides being tolerant of a wide range of soil conditions. It grows best on the less acid and neutral soils, and regenerates very freely on moist, not too weedy, land.

Sycamore is not a satisfactory tree to raise in mixture with several other species, as unless it is closely crowded it speedily becomes a wolf, and then there are few more ugly and unprofitable trees. Grown in mixture with larch, provided the soil is suitable for the latter species, clean straight poles can be obtained.

Sweet chestnut. The date of introduction of this tree into Britain has been a subject of controversy, but it is generally held to have been brought in by the Romans. It is widely distributed in mixed woods both in England and southern Scotland, where it often grows to great size. It does best as a timber tree on deep sandy or loamy soils, but as the timber is often twisted and shaky, it is rarely planted now except for coppice.

Birch. This tree, though widely distributed throughout Great Britain, especially on sandy soils, is regarded by almost all foresters as a weed to be cut out of a plantation as soon as it makes its appearance. Birch is never grown pure as a forest crop—it is planted sometimes for game purposes—and where it occurs in extensive areas, as in parts of Wales and the Highlands of Scotland, these represent usually the remains of natural forests, and come more under the heading of scrub than of forest. The pubescent birch is the principal species in the mountainous parts of Britain and on boggy land, while the smooth-leaved form, *Betula verrucosa*, occurs mainly on dry sandy formations.

This tree is hardy, regenerates very freely from seed, and will grow under a

wide range of conditions. It is much esteemed in Sweden for the beneficial action of its leaves on pine and spruce needle humus, and according to Hesselmann the conifers often fail to regenerate in its absence. Birch is also much used in Denmark as advance growth over oak and beech sowings (against late frosts). Probably it has a greater silvicultural value for this country, especially in the North of Scotland, than is generally recognized.

Alder and Poplar. These are trees of marshy low-lying ground and play no very important part in British forestry. Alder occurs mainly in wet hollows, sometimes pure and sometimes in mixture with poplar and willow; it is more usually grown in coppice than as high forest.

Poplar has recently come to the fore as a possible species for planting up derelict coppices on heavy soils at low elevations, but it is more common as a road-side tree than in plantations; growth is very rapid in moist porous soils, but little is known as to its minimum soil requirements.

COPPICE-WITH-STANDARDS.

A considerable proportion of the area under hardwoods in Great Britain is occupied by woods grown under this system. Until comparatively recent years it was the main system practised in this country, and nearly all the oak timber standing to-day has been grown as standards over coppice. There is often a sprinkling of ash, and, in the chalk areas, of beech, among the oak standards, but in most districts oak forms the greater proportion of the crop. The principal species composing the coppice are: oak, ash, hazel, Spanish chestnut, beech, birch, alder, hornbeam, sycamore, and aspen. The coppice is usually mixed, but in some districts oak, ash, hazel, and Spanish chestnut form pure blocks of considerable extent. The rotation varies for the different species: it is usually short (six to ten years) when there is much hazel in the crop; ash and Spanish chestnut are generally grown on ten- to fifteen-year rotations, while the slower-growing oak usually requires much longer periods—up to thirty to forty years in shallow soils—before it is saleable.

Prior to the Industrial Period in Britain there is no doubt that these woods were very profitable; coppice-grown oak timber was in large demand for the Navy, as well as for general building construction, while important rural industries obtained their raw material from the coppice. The use of steel for ship-building, together with the development of trade with foreign countries, has completely altered the position, and now there are relatively few uses for which any but the best coppice-grown oak timber can compete with imported timber from America, Austria, and other countries, while the coppice itself is unsaleable over large parts of Britain.

At one time coppice-with-standards woods were carefully and systematically treated, the coppice filled up each time it was cut, and tellers stored in correct proportion to replace the standards removed. With the loss of a good market, however, these cultural measures were usually allowed to lapse and the typical coppice-with-standards wood of to-day is a mere travesty of what it should be. One notable feature is the scarcity of natural oak seedlings when the coppice is cut over. Whether the disturbance of the balance of nature, due to extermination of predatory vermin and the superabundance of rabbits, is responsible is an open question, but it is remarkable how little oak regeneration there is in the coppices generally. Excessive cutting of the best trees during the last thirty to fifty

years, combined with the recent series of bad Tortrix years, have left the remaining standards in a deplorable state, and in most of the woods the trees are thin on the ground, short boled, and frequently stag-headed.

The treatment of these woods in their present more or less derelict state is a matter of much perplexity. It is obvious that they should be converted into a more productive form of woodland, but how this is to be brought about in practice is the problem. When the coppice contains a considerable proportion of hazel, birch, or hornbeam, conversion to high forest is clearly impracticable, while if the area is clear felled and replanted with conifers or hardwoods the cost is often too high for private owners, especially when the necessity of intensive cleaning during the first few years to protect young plants against coppice shoots is taken into consideration. In addition, the same problem arises as in the case of high forest oak, namely, the question, if replanting is decided upon, as to whether the land should be brought under hardwoods or under conifers. The soil may be deep and apparently rich, but, if the existing standards can be taken as any sort of criterion, the land would appear hopeless for growing oak in the future. In the writer's opinion it is necessary to discount the condition of the standards pretty heavily; in many cases they represent only the least thrifty members of the original stock and can serve as little guide to the future development of an even-aged crop of oak grown on correct silvicultural lines.

It may be of some interest to outline the methods followed by the Forestry Commission in restocking coppice-with-standards areas in which all the standards have been cut prior to acquisition by the Department. The normal procedure is to cut the coppice, if not more than three years old, in drifts 3 feet wide and from 4 to 6 feet apart. The young trees, hardwoods or conifers as the case may be, are planted up the middle of the drifts and the coppice shoots kept cut back on each side until the plants are safe from suppression. With fast-growing conifers such as larch and Douglas fir the process is not unduly costly, but oak and ash are much slower in getting away and four- and five-year-old plantations are not yet out of weeding.

COPPICE.

The principal species found in plain coppices are oak, ash, Spanish chestnut, hazel, and beech. Of these, oak probably occupies the largest area, its use as coppice dating from the times when oak bark fetched a good price and when there was always a market for the small poles as charcoal, firewood, and the like. With changing conditions oak coppice has become practically valueless and coppices which have not been cut for thirty to forty years are of frequent occurrence. On the better soils, especially where there is an admixture of beech, these coppices can often be converted to high forest, producing quite satisfactory stands, but on the shallower soils nothing remains except conversion to conifer. Where there is no demand for the coppice this is an expensive business. To clear, fell, and burn the crop costs from £4 to £10 per acre, and then there is the cost of planting the new crop. Experiments are being carried out by the Forestry Commission in Devonshire on the lines of opening the canopy by 'ringing' the larger stems and underplanting with Douglas fir. It is too early yet to say whether success is likely.

Ash and hazel coppices were at one time very profitable crops; grown on a short rotation, they often gave a net yield surpassing that of adjoining agri-

cultural land; but now that the demand for small stakes of all kinds has dwindled so greatly and the market for mature coppice of these species is usually slow and uncertain, such coppices are best converted. The dying out in many districts of the old race of underwood craftsmen is partly responsible for the poor state of the coppice trade.

The one species which still pays, and pays well, to grow as coppice is the Spanish chestnut. The demand for well-grown chestnut coppices for making split-pale fencing is very keen, and prices up to £50 per acre have been realized during the past year or two. Kent, Surrey, and Sussex are the counties in which most chestnut is grown, and within this district it has been planted on a wide range of soils. The tree grows well on sandy loams, loams, and clays, but moisture and depth appear to be the two main requirements. The rotation is usually from ten to twelve years, although in Kent, where there is a demand for chestnut coppice for hop poles as well as for split fencing, somewhat longer rotations are favoured.

SCRUB.

The recently completed Census of Woodlands has indicated the existence of a surprisingly large area of land under scrub in Britain. There are two main types, oak scrub and birch scrub, and both are practically confined to the mountainous districts of England, Wales, and Scotland. The most important areas occur in the Scottish Highlands, where a belt of oak scrub runs round the foothills, sending tongues up the main valleys; the birch-scrub zone joins the oak at the upper limit of the latter and often runs far into the mountains. These Highland scrub areas represent in part the remnants of the once great Caledonian Forest; they are usually on good soil very favourable to coniferous growth.

The replanting of these scrub lands meets with two serious obstacles. In the first place, owing to the distance from centres of utilization, the oak and birch are often unsaleable, and, secondly, experience has shown that conifers planted on these soils are particularly liable to attack by the root fungi, *Fomes annosus* and *Armillaria mellea*. The first difficulty has been overcome to some extent by ringing the trees at the butt, and when carefully done this is both cheap and effective.

UTILIZATION OF SOFTWOODS IN GREAT BRITAIN

BY JOHN T. SMITH

LUMBERING and the conversion of forests into commercial products are still insignificant in this country. They are probably the oldest industries, having necessarily come before agriculture. Except during the War they have never been developed or even encouraged to develop. It is difficult to understand why, because to-day the annual consumption of wood is nine or ten times what is taken from the existing forests of the United Kingdom. This country began to import timber about the eleventh century, and there is no doubt that since that date the virgin forests of the world have supplied this country with cheaper timber than can be derived from commercially grown woods. The ability of the timber-exporting countries to market their own wood fuel and waste outside of this country and the disappearance of such markets here, due to the development of coal and oil fuel, are factors in the situation. The paucity of crops in this country and the substitution during the past fifty years of log importation by highly manufactured wood goods, produced abroad on a great scale with greatly developed modern plants, under keen competitive conditions and with minimum hand labour, have effectively curtailed the efforts of the native timber trade.

The reasons which have brought about a 90 per cent. consumption of softwoods in this country are well enough known. Equally known is the fact that the largest areas of commercial softwood trees in this country are to be found in the northern part of Great Britain. So it may be convenient to develop these notes mainly from experience in Scotland. The members of the home timber trade in England are represented by various trade associations all federated in one large association, the membership of which is 250. This membership represents probably 75 per cent. of the total output of home timber in England, by far the largest part of which is of hardwoods. In Scotland there are two associations similarly representing 75 per cent. of the output, with a combined membership of 113. The number of sawmills in England is unknown. In Scotland the number of active sawmills is about 300, inclusive of members of the trade outside the associations. Of these 300 mills few, if any, may be said to be exclusively hardwood mills. They are mostly driven by portable steam-engines of 10 to 12 horse-power and some 30 per cent. of them are permanently situated, the largest plant being probably not more than 100 horse-power. Nearly all types of power plants are represented, electricity, gas, oil, and steam, or a combination of these. Circular saws (swage saws of narrow gauge) for the most part are used, but some of the mills are equipped with band and frame saws, planing and moulding machines, and to a limited extent practically all the types of machinery employed by the foreign mills are to be seen at the homewood mills of the larger towns.

They derive their supplies from small scattered forests containing now very limited supplies of lumber which could be classed as first grade according to the Scandinavian standard. There is only one indigenous softwood tree in this country, viz. Scots pine. The other softwood trees of importance, larch, spruce, and silver fir, were introduced little more than two hundred years ago, while the Douglas fir and the Sitka spruce came just one hundred years ago.

The home timber trade of this country cannot therefore claim to have had much experience in handling mature softwood crops. The uses to which these species are put follow closely the uses of imported timber and subject only to lengths and breadths are, with the one exception of wood-pulp manufacture, to be found in every industry where wood is used. The Scots pine is identical with the redwood of Northern Europe although not so slowly grown. Spruce is just the same whitewood which comes from the same sources. Redwood has advanced in price more rapidly than whitewood during the past century, and for that reason whitewood is now in greater demand in Scotland, but the recent advance in price of whitewood due to the demand for wood-pulp may affect the situation in the future. Much more redwood is used in England.

SCOTS PINE AND SPRUCE.

The following is a picture of the recent conversion and marketing of a Perthshire lot consisting only of Scots pine and spruce trees. A 12-horse-power portable engine which was bought second hand seventeen years previously and was twenty-four years old, having seen service on six previous sites throughout Scotland, was installed with wood benches to drive four circular saws, a breaking-up saw, a slabbing saw, a stave saw, and a crosscut saw. The wood required to make the engine house, sawmill sheds, and bothies for the mill squad was first cut from the wood around the mill stance. There were 3,250 trees (2,840 of them being Scots fir) containing, according to the grower's estimate of them as standing trees, 55,000 cubic feet. A year was given to clear this lot, and the work was spread over and accomplished in that time. The trees produced 26,000 cubic feet actual measurement of boards mostly under 1 inch thick, none exceeding nine feet in length; the breadths ranged from 12 per cent. under 5 inches to 80 per cent. 5 inches to 9 inches and the remainder over 9 inches, none exceeding 11 inches. In addition there were produced some 6,000 cubic feet of sawn pit props and other mining timber. The slabs and waste, including the sawdust, were used as fuel for the engine or disposed of locally for very little. One-third of the trees were summer felled. Mechanical tree fellers are little used in Scotland owing to the configuration of the ground. Nor did the operations in this case require any special methods of dragging, sliding, or forest railway, so often a feature of the work. The trees were crosscut and trimmed as they fell, but not peeled. Twenty months after the commencement of sawing, the last loads were dispatched to the markets, six to eight months being allowed for air seasoning. The material produced was all cut oversize to allow for shrinkage. The markets were the Scottish collieries in Lanarkshire, Ayrshire, Stirlingshire, Fifeshire, and the Lothians. A little went to Northumberland collieries. Most of the boards went to boxmakers, some to other timber merchants for special uses as required. The total amount expended in transport, including dragging and carting to the sawmill, carting to the railway, and railway carriage, was in this case equal to the whole of the price paid to the grower for the standing wood. At the box factories from which the boards and box sets or shooks were railed again in many instances, the boards were converted into packing cases, crates, and boxes used for the conveyance of merchandise in almost every other industry. Some of the boxes with their contents are exported to all parts of the world and this is one of the few forms in which home timber is exported from this country. Some of the Scots pine boards were cut specially in

the form of barrel heading and the spruce in the form of staves for herring barrels. The loss in sawing, viz. 42 per cent., may seem high, but the boards were thin and there was much sawing and selection. It is contended that the conversion of this type of wood into trade deals and battens in the long lengths usually imported would produce too much unmarketable waste. This is one of the principal reasons why the home timber trade cannot supply material for the building trade.

LARCH.

This is probably the only softwood grown in this country for which there may be said to be a market for the whole tree. It suffers little from imported larch, as the supply of Siberian larch has not resumed to any extent since the War. Irish larch of inferior quality causes undue restriction in price in Scotland and the North of England. The point of the tree is valuable for sheep-net stakes, raspberry or rose stakes. They are preferable to young thinnings, which are not so durable. The next 30 to 40 feet of the tree provides pit props, pit-wood, rick props, mining poles, foundation piles, and light telegraph poles. The remainder of the tree, according to size, produces marketable timber from 5 to 9 inches quarter girth (Hoppus) measurement, mostly cut into fencing posts, paling rails, spars, stays, straining posts, gate posts, gates, &c.; timber over 9 inches and up to 12 inches quarter girth is cut into hutchwood for the collieries, sawn mining timber, waggon wood, barrow, lorry, and cart wood; and the root cuts, if sound, contain very valuable timber for boat-building, constructional work, railway sleepers, and so on. The branchwood and thinnings have a useful though restricted market for rustic work, garden furniture, &c. The North Country larch is very durable, but the West Coast larch is exceedingly disappointing, being too quickly grown and when sawn up containing frequently many black knots. The market for bark for the leather industry has disappeared since the War.

OTHER SPECIES.

The other softwood trees are generally marketed as redwood or whitewood without regard to any special qualities they may have. There is not sufficient of any one species for continuous markets. Some Corsican pine in Wigtownshire was found by the writer to be almost unmarketable. It was overgrown with ivy and was very coarse. The Douglas fir is a disappointing tree to the trade, being much too rapidly grown. It is cut into sleepers and mining timber. It is useless for boxmaking and as grown here cannot hope meantime to compare with the Oregon or British Columbia Douglas fir, which as every one knows is a very valuable wood.¹ So far no commercial distinction has been possible between the Sitka (silver spruce) and the Norway spruces of Scotland. The writer has not heard of any native-grown Sitka spruce being used for aeroplane construction, although the imported Sitka spruce is eminently suitable for that work. Recently shingles were cut as a special experiment from some *Thuja plicata*, but the loss in sawing and discarded shingles amounted to no less than 56 per cent., the sawing being found to be difficult and very costly.

The railways, mines, ship-yards, box factories, and agriculture take up about

¹ Editor's note: The Douglas fir grows almost as quickly in youth in its own country. The timber sent into this country from British Columbia and Oregon is, however, from old trees of such dimensions that the inner wide-ringed zone can be excluded. The same applies to Sitka spruce.

two-thirds of the entire production of home softwoods in this country. Furniture-making uses but little. Such, then, is a brief outline of the utilization of softwoods in this country and an industry for which the War was a disaster except in respect that it brought about the birth of the Forestry Commission, with the prospect of a more plentiful supply of home timber for the future. The foresters of Great Britain have at least two serious problems confronting them. The high classification of timber by the railway companies in this country requires alteration so that the cost of transport by rail will bear a reasonable ratio to the value of the traffic carried. By far the more serious problem, however, is the growing of first-grade lumber in the quickest possible time to replace and augment considerably the third- and fourth-grade crops of softwoods which unfortunately predominate. Perhaps the best encouragement they can have is the knowledge that under like conditions home-grown timber has been proved repeatedly to be superior in strength, toughness, and appearance to imported timber.

THE MARKETING OF BRITISH HARDWOODS

BY J. H. NEWNHAM ('ACORN')

THE term 'hardwoods' used in connexion with home-grown commercial timbers is somewhat of a misnomer and vaguely represents one of two groups into which the timber industry has roughly divided British trees—the other group being 'softwoods'. Sometimes they are described as 'deciduous trees' and 'conifers', although the latter term includes the larches which, actually, are both deciduous and coniferous. Again, the name 'hardwood' used in this connexion might be most misleading to any one who was unaware of its elasticity, particularly as deciduous varieties include the willows, poplars, elms (*Ulmus* species), horse chestnut, and lime tree, all of which most decidedly are 'softwoods'. I am inclined to think that if we spoke of 'broad-leaf trees' and 'coniferous trees' we should use a better and much less misleading description.

The actual uses of broad-leaf and coniferous timbers differ so widely that the two groups might be looked upon as representing separate branches of the timber trade, and in the limited space of this article I propose leaving the uses of coniferous woods entirely alone.

Although there are between twenty and thirty distinct varieties of home-grown commercial broad-leaf timbers, four stand out well in front of all the others in industrial importance, namely, oak, ash, beech, and elm. The group next in importance may be said to include Spanish chestnut, sycamore, birch, lime tree, horse chestnut, and black poplar. All of the remaining species have their individual uses and values, but they are not in such general demand as these two groups.

From an historical point of view it should be of considerable interest to the student to endeavour to ascertain why the process of selectivity through the centuries has finally given oak, ash, beech, and elm the pride of place amongst British timbers. It may have been due originally to a greater natural profusion of these species, causing them by their greater commonness to be used on a more widespread scale, and thus establishing them more firmly for general and industrial purposes than other varieties. I think, however, that the general conclusion would be that they have gained their present position, more than for any other reason, by a sheer appreciation of their actual merits alone, through a long period of practical experience, during which they had been tested exhaustively, and definitely proved as being more suitable than any other kinds for the special purposes for which they are used to-day.

Although the uses to which home-grown hardwoods are put are many and varied, owing to an ever-increasing competition, mostly from imported timbers, the market is subject to frequent and unexpected changes. What to-day may be looked upon as a permanent outlet for various home-grown woods may be definitely closed against them to-morrow. As an instance of the changes which are taking place I may mention the ash handle industry, particularly that section engaged in manufacturing handles for hammers, spades, shovels, hay and manure forks, picks, and hatchets. Fifty years ago there were many thriving firms of makers scattered here and there all over the country. Practically all the blanks for their handles were riven out of round timber, thus ensuring strength and durability, being finished by a skilful use of the draw knife, or by hand in

a turning lathe. Undoubtedly the workers in these businesses were the most expert handle makers in the world, and as far as could then be seen they apparently occupied an impregnable position in a permanent industry. But the more up-to-date Americans began to manufacture handles from sawn blanks turned by either copying or automatic lathes, and by sheer force of efficiency and organization swamped our markets and virtually killed our own manufacturing, except in a few isolated cases where American methods were adopted.

A similar fate has overtaken the oak spoke business. At one time no self-respecting wheelwright or coach builder would dream of putting any other kind of spoke into a wheel than one that had been properly cleft and hand dressed. But the Americans produced a sawn and machine-turned spoke which has driven the cleft variety off the market except in the case of rare sizes and unusual requirements. As in the handle-making industry, American methods have been adopted by the few firms of wheel-makers in this country still remaining in the business, which, in its turn, is being gradually crushed out by the rapid growth of the use of motor vehicles equipped with steel wheels.

In many ways we are ourselves largely to blame for losing our own home markets for home-grown timber products through not keeping up to date in our ideas and methods, and not giving consumers the goods they actually require. There can be no doubt whatever that we should find a far healthier tone prevailing in the market if our goods were offered to potential buyers in better condition than has been the common practice. The home-grown timber industry has a great deal yet to learn from the methods of preparing timber employed by producers in exporting countries; and the sooner it realizes the position the better, namely, that it is in competition with a highly organized trade which carries out selection, grading, and conditioning in a very scientific manner, which hitherto our own trade has made no really serious effort to emulate.

We cannot, however, overlook the fact that all the conditions governing the growth, disposal, and utilization of home-grown timber are extremely unsatisfactory, and in any plans that may be made for improving and consolidating existing markets, before looking for new ones, the following points must be carefully considered if permanent business is hoped for, viz.

- 1st. Are constant supplies available?
- 2nd. Can quality be guaranteed?
- 3rd. Can timber be properly conditioned before delivery?
- 4th. Is it possible to compete in price with imported timber?

In dealing with the first point we are confronted with several formidable factors of a very disheartening character. Speaking generally, broad-leaf timbers have been grown in a most haphazard sort of way. In many cases they have been allowed to grow with some idea in the owner's mind that they had a kind of market value, and represented an asset which could be realized when it was necessary to raise a bit of ready money; but, with few exceptions, there has been next to no intention of growing them on definite lines for specific industrial purposes, nor with any idea of producing timber on the principle of rotation crops and of such excellent quality that it would create a market for itself and maintain this market permanently.

If we take the country as a whole, with the exception of certain districts in Scotland, we more often than not find broad-leaf and conifer mixed indiscrimi-

nately in woods and plantations, unless the locality happens to be one in which self-regenerating species have gained the upper hand, and have predominated to such an extent that landowners have not bothered at all about planting. Mixed plantations in which almost every conceivable variety of broad-leaf trees can be found may perhaps be representative of an aesthetically attractive system of silviculture, but they are most unremunerative from a commercial point of view, both to landowner and timber merchant, when they are sold *en bloc* for clear cutting. The chances are very remote that the purchasing merchant will have an established trade for all the varieties of timber included in his purchase, however well grown they may be. This means that a certain percentage of the plantation is an absolute speculation on his part, and it may be taken for granted that his valuation of this percentage will be very low in order to cover the many risks he is running. The landowner, therefore, cannot expect to command such a high price for his plantation, in proportion, as if he were disposing of selected species all of which were in general demand. Then again, not only are species very much mixed in these plantations, but each species itself usually varies to such an extent in qualities in the same plantation that it is impossible to establish uniformity in either quality or value.

But if sufficient quantities of all varieties of timber to meet demands were forthcoming, the grading of qualities could be carried out and the mixing of species would only be a minor drawback. Unfortunately, though, supplies generally are too uncertainly intermittent. The deplorable, but probably inevitable, process of breaking up large estates which has been going on since the War has brought large quantities of home-grown timber into the market, far in excess of what existing resources can spare economically without threatening early exhaustion. This timber has been sold during a period of industrial depression, and has glutted the usual avenues of consumption, thereby resulting in low prices and temporary over-production. This, combined with the depletion of resources during the War, represents a serious shortage in our national stock of standing timber which cannot be replaced for two or three generations. Under the circumstances it appears very doubtful whether constant supplies at the present rate of consumption could be maintained indefinitely, as a strong probability exists that when the present rate of breaking up of estates has run its course, and the land becomes held in more durable perpetuity than now, the new owners on purpose to preserve the amenities of their estates will make great efforts to conserve their woods and plantations, and thus will automatically curtail supplies to the consumer. This eventuality will come about gradually and may not be perceptible for some years, but I think it is practically certain to occur in course of time, unless the true interests of commercial forestry will be sufficiently strong to induce landowners to sell their timber as it reaches maturity, and therefore its greatest marketable value, and replant their woods upon proper scientific lines.

In dealing with the second point—‘Can quality be guaranteed?’—we are undoubtedly faced with very great difficulties if present unmethodical customs of offering standing timber for sale are persisted in. I have already mentioned the difficulties of maintaining qualities when mixed plantations are sold for clear cutting, and there is no necessity to enlarge upon this unduly. We have, however, to face the fact that it has been the custom on a good many estates, when timber has been marked for sale, to select an excessively large proportion of

malformed and diseased trees—leaving nearly all the best timber standing, even when some of it has passed maturity. From a point of view of estate improvement this may be a good policy within certain limits, but if the home-grown timber industry possessed no other sources of supply for its raw material the poor quality of such timber would depreciate the market so rapidly that the industry would practically disappear, particularly as imported timber of excellent quality and condition can be obtained very easily as a substitute by the consumer.

Although the home-grown timber industry, in common with most other industries, has been in a state of depression for some considerable time, a more or less ready market has always existed for really good timbers and at good prices. Competition is so keen to-day that only goods of high quality can be certain of holding their own permanently, and if the grower is unable to offer timber up to the standard demanded it naturally means that he will find timber-growing extremely unsatisfactory and unremunerative, an experience which is bound to be the same, also, of the timber merchant who has nothing but timber of an inferior character to offer his customers.

But apart from the deliberate offering of his worst-grown timber by the landowner we find, in dealing with this question, that we are faced with the tremendously disproportionate percentage of inferior quality amongst every kind of deciduous timber growing in all parts of the country. This timber has got to be dealt with at some time or other, because in very many instances its removal is essential for replanting purposes. Under the best of conditions its market value is low, and it is a mistake to mix it with good timber when selling, as the basis of a timber merchant's buying is usually controlled by the worst rather than the best qualities. I think on the whole, even if the same parties only are interested, the grower will find it to his interests to make two distinct transactions—one for his best qualities, and the other for his inferior qualities—when a thinning and not a clear cut is proposed.

I am afraid, when we take this great proportion of inferior qualities into consideration, that the establishment of standard qualities for home-grown timber in the round is not a practical possibility at the present time, although I am quite convinced from a long experience that great improvements might be made in marketing, if a closer co-operation existed between growers themselves combined with a better general understanding between producers and consumers.

In any case, the eventual establishment of standards of grading for round timber is a goal well worth aiming at and could be advantageously kept in mind by all who are responsible for replanting and reafforestation schemes.

With regard to the third point—'Can timber be properly conditioned before delivery'—this might appear to be a matter more for the converter than the grower, but the latter has a certain part to play if timber is to be put on the market in the best possible condition. The home-grown timber industry is confronted with an ever-increasing competition of imported woods which have been seasoned—usually artificially seasoned—so that consumers to-day can have supplies ready to use immediately upon delivery, and, therefore, are not compelled to set aside a considerable portion of their capital for stocking timber for years to season, as they were compelled to do up to a few years ago. Although the home-grown timber industry is very slow to adopt new and improved

methods, the very weight of the pressure of this outside competition will compel it to come into line before long as a matter of sheer self-preservation.

Now all broad-leaf timbers, in order that their values may be as unimpaired as possible, should be felled in winter time, and landowners can insist upon this being done, not only for the sake of the timber, but in order that it shall be ready for removal as soon as conditions permit, thereby preventing crops being damaged unnecessarily. It is a small part perhaps, but it is as much to the grower's interests that the best possible reputation of home-grown timber should be maintained and the market preserved, as it is to the timber merchant's.

Finally, in dealing with the question 'Is it possible to compete in price with imported timber?' I should be inclined to reply in the affirmative, speaking generally. There have been times, and will be again probably, when imported timbers have been put on the market at ridiculously low prices, but, on the whole, the best qualities are usually sold at a good figure. There are no means in existence at present for stopping a glut of imported wood, but with increasing demands abroad and gradual depletion of resources, the probabilities of the future appear to tend towards a slow but sure increase of prices rather than a decrease. If the general qualities of home-grown woods can be improved, and if these woods are put on the market in a sound and ready-to-use condition, and if supplies are forthcoming to meet demands, there is nothing to fear for the future. We have to remember that the reasons why home-grown timbers are not so much in demand to-day as they might have been are that:

- (a) Supplies were too uncertain.
- (b) Qualities were too unreliable.
- (c) Prices were not consistent with qualities.
- (d) Timber was too often delivered in a green instead of a seasoned condition when the latter was demanded.

For these reasons only, users have been driven to use imported woods for their requirements, but as soon as home-grown timber can be offered in accordance with the conditions I have endeavoured to explain they will again have the run of the market.

THE PRESENT POSITION OF FOREST ENTOMOLOGY IN GREAT BRITAIN

BY J. W. MUNRO

IT is only within recent years that forest entomology has been recognized in Britain as an essential branch of forestry science. Until about twenty years ago the questions of the injuries caused by insects in forestry, and of the ways and means of checking them, were regarded as minor problems in the branch of forest protection, and such accounts of common or important forest insects as were available to the forester were to be found in the Forest Protection section of the well-known manuals of Schlich and Nisbet. These accounts, moreover, were based on, or were even mere translations from, the German text-books of which Hesse's and Henschel's were the chief, and little attempt was made in them to indicate how far the habits and life-histories of the insects described were true of our peculiar insular and forest conditions, or to show how the control measures recommended were applicable to British forestry practice.

The first factor which led to a breaking away from the stereotyped forest protection methods of treating forest entomology appears to have been the outbreak of the Large Larch Sawfly in Cumberland in 1905, an outbreak which persisted until about 1913. Here was an instance where the German text-books rendered only the slightest help and where finally the assistance of the entomologist proper was sought. It is probable that the problems presented by the Large Larch Sawfly outbreak were important as suggesting that Great Britain had its forest insect problems and forest insect conditions distinct from those of the Continent.

In 1908 our first text-book of Forest Entomology was published by the late A. T. Gillanders, and although it cannot compare with such classics as Judeich, Nitsche's *Forst-insektenkunde*, and Packard's Fifth Report to the U.S. Entomological Commission, it represented a definite attempt to describe our forest insects and broke away from the 'forest protection' tradition.

Meanwhile in 1909 Dr. R. Stewart Macdougall instituted in Edinburgh a short course in forest entomology as part of the forestry course in the University, where he had already begun the first-hand study of some of our more important or more common forest insects. His study of the biology of the pine weevils of the genus *Pissodes*, begun in Munich and continued and completed in Edinburgh, is the first original contribution made to British forest entomology. To it, and to the subsequent work of Dr. Macdougall and his pupils, Edinburgh University owes its prestige as the leading school of forest entomology in Britain, and while in the forestry schools of our other Universities forest entomology has been taught for some years past, reference to recent forest entomological literature shows that the major part of the research work in the subject has been done or inspired by the Edinburgh school.

One of the chief advances in forest entomology has been the study of some of the more important forest insects, not as pests to be eradicated but as interesting members of the forest fauna. While to study an insect because it is the cause of more or less serious loss to a forest crop is often to the official mind the only reason for studying it, such a study can never be so rich in results as

that carried out from the broader outlook of the trained scientist to whom the status of the insect as a pest is less important than its relation to its environment and its modes of survival and increase. The progress made during the last ten or fifteen years in forest entomology is almost wholly attributable to the growth of this broader outlook, and, while it may be many years before that outlook becomes general, much good work can be done by those workers who have the courage to adopt it.

Another advance in our forest entomology is the recognition of the fact that we have in Britain insect problems distinct from those of the Continent. Some of these arise because our foresters to-day are planting exotic trees which are still viewed with suspicion by other European countries. Thus with the extensive planting of Douglas fir and Sitka spruce we have the problems presented by the Douglas fir Chermes and the Spruce Aphis, problems unknown on the Continent. But apart from these, such problems as are presented by the chafers in our forest nurseries and by the weevils and bark-beetles in our plantations and woods are quite distinct from those on the Continent, even when they are caused by the same species of insect.

Among the micro-lepidoptera similar contrasts occur. *Steganoptycha pini-colana*, known to continental foresters as the 'grauer Lärchenwickler', is with us chiefly injurious not to the larch but to the Scots pine, and a survey of the insect conditions prevailing when once our recently formed plantations have closed canopy will undoubtedly show that we have still other insect problems peculiar to this country.

Good progress has been made by individual workers in the study of some of the more important of our forest insects. The work of Steven on the Chermesidae, confirming Marchal's work on the group in France, and Chrystal's more recent work on *Chermes cooleyi* and *Dreyfusia nüsslini* have laid a foundation for further work. The ecology of the pine weevil '*Hylobius*' has been studied and has thrown new light on the means of controlling that pest of the replanted area. A general survey of our bark-beetle conditions has been made, and the main features in the life-cycles of our chafer beetles have been roughly ascertained. So far forest entomology has justified itself, but there are still many problems untouched. The large and important group, the micro-lepidoptera, has scarcely been studied at all. The general life-history of the green oak Tortrix has been studied and the all-important part played by weather conditions in governing the rise and fall in the numbers of that moth is sufficiently clear; but such moths as the pine-shoot tortrices and the numerous leaf- and shoot-mining moths of the spruce have been almost wholly neglected. Some of these insects are already injurious in East Anglia and in the Border districts, but once our plantations close canopy it is to be feared that the injuries they cause will increase and spread. Other problems will arise with the commencement of thinning operations. The longicorn beetles, the weevils, and the bark-beetles, at present merely secondarily injurious, will then assume greater importance, and already there is urgent need for work on these groups along the lines of investigation carried out by Craighead and Graham on the longicorns in the United States and by Trägårdh on the weevils and bark-beetles in Sweden.

And still there remain the problems caused by the defoliators, some of which have already been mentioned: the pine-shoot tortrices, the tantalizing Tineids, the geometers, and the sawflies. So far we know nothing of their economy;

what parasites attack them, what weather and forest conditions favour them: on all these questions we are still in ignorance.

Then there is the difficult question of imported forest pests. Although we in this country have seen the silver fir abandoned as a forest tree because of the injuries to it caused by *Dreyfusia nüsslini*, have been made to realize that the imported chalcid wasp *Megastigmus spermotrophus* has destroyed all hope of our rearing Douglas fir from home seed, and have witnessed in quite recent years the rapid spread of *Chermes cooleyi* on Douglas fir, the means to be taken to prevent further importations of pests have still to be considered. The measures adopted by the Ministry of Agriculture of inspection of imported plants at the ports are excellent so far as they go, but they are not considered wholly effective, and the best safeguard of all, an efficient forest entomological service, has still to be built up. It is of little use to call for entomologists when once a pest has got a hold in a new country. In the first place, trained entomologists are not always available, and even when they are, they can render little help unless they are familiar with the problems they have to solve.

In all the insect problems affecting the establishment and growing of forests in this country there is ample scope for valuable work, and to those who can look forward there is an urgent call for such work.

In the utilization of our forests and of imported timbers in this country forest entomology is also playing its part. As with forestry proper, so with forest products, the insects have made their presence felt, and again the researches of individual workers in entomology are being utilized to the full and have justified the granting of official support. At present the most urgent forest products problem in entomology is that created by the importation into this country from America of large consignments of ash and oak infested with the grubs of the *Lyctus* beetles. These beetles have already caused very serious loss in the furniture trade, but thanks to the earlier work of the entomologists, and, in particular, of Altson in this country and of Snyder in the United States, there is already good reason to hope that before long methods will have been devised to control the *Lyctus* beetles locally and to reduce the importation of *Lyctus*-infested timber into our home timber yards. Research, too, has been approved on the beetles affecting timber in buildings, which will continue the work on the Furniture beetle and Death Watch beetle begun by the late Professor Lefroy and by Dr. Gahan.

On the whole, despite the many problems awaiting investigation, progress in entomology has been sure. Like forestry itself, forest entomology is in its infancy. With the growth of forestry and the nearer approach to a broader, sounder forest policy, forest entomology will also expand. It has survived the trials of infancy and there is now no reason why it should not attain to a lusty manhood.

FOREST PRODUCTS RESEARCH IN GREAT BRITAIN

BY MAJOR F. M. OLIPHANT

AT a recent American Congress on the Utilization of Timber the startling estimate was made that only about a third of the volume of a tree—which Nature has taken many decades to produce—is actually utilized after the tree is felled for timber.

Aside from unavoidable waste in felling, conversion, and manufacture, a further large but *avoidable* waste occurs, partly during these three processes, partly through poor methods of storage and seasoning (both in yard and kiln), partly through decay and insect attack, and partly through unsuitable conditions of use.

Decay is probably the greatest source of loss after the tree leaves the forest. It exacts a large and increasing toll from timber in the yard and in buildings, from sleepers, pit-props, pulp material, and the like. The annual expenditure on the maintenance and replacement of timber is known to be enormous. Wasteful methods of conversion and utilization are responsible for further heavy losses: there is heavy loss in seasoning; the saw-miller finds it difficult to utilize his off-cut, slabwood, and sawdust; waste is incurred in cutting out small-dimension stock; larger sizes than are necessary for safety are often used, while a particular wood is insisted upon where another would be cheaper and technically just as well, or even better, suited to the purpose.

Compare with these considerations the fact that for one item alone, namely, timber imported from abroad, the average annual value is some fifty million pounds, not to mention either the value of innumerable products derived from wood or our consumption of home-grown timber. It at once becomes evident that even small savings here and there would mean, in the aggregate, a considerable national economy. Further, if the facts be set in relation to what is stated about the world's dwindling forest resources, then efficient utilization is co-partner with reafforestation—for a tree saved is a tree grown!

Defective utilization calls for a threefold remedy: to broadcast all available knowledge, to endeavour that it shall be put into practice, and continually to seek for new knowledge. In this there lies the need of a technical organization as the source of information and research; and this organization must be in sympathy and close touch with every phase of the timber industry, for only so will its work be kept in thrifty and practical lines and the results find acceptance with the trade.

Following a recommendation by the Imperial Forestry Conference of 1920 the British Government established, under the Department of Scientific and Industrial Research, a Forest Products Research Board with the duties of organizing and carrying on research into the utilization of timber and other forest products. A very close survey of the situation was made by this Board, involving an exploration of activities and methods in this and other countries and the building up of liaison with other centres of research. At the same time investigations were started with such limited facilities as existed, under temporary arrangements which could easily be revised in such measure as the progress of the preliminary survey should dictate. Eventually, a review of circumstances and needs, as disclosed by this survey, led the Government to set up a Forest Products Research Laboratory, and in October 1925 a per-

manent Director, Mr. R. S. Pearson, C.I.E., F.L.S., late Forest Economist at the Indian Government's Forest Research Institute, Dehra Dun, with many years' experience, was appointed to organize and direct the work. A site was acquired at Princes Risborough, Buckinghamshire, and it is expected that the laboratory now in course of erection will have been built, equipped, and staffed by August 1927. Princes Risborough is 16 miles south-eastward of Oxford, thus facilitating close touch with the Imperial Forestry Institute, and communication with London (35 miles) and other industrial centres is good.

The Laboratory has been organized under different sections which, with the objects of their work, are as follows:

<i>Section.</i>	<i>Typical subjects of study.</i>
I. TIMBER MECHANICS.	Strength properties of timber; influence of defects; influence of treatment (e. g. seasoning, preservation).
<i>Key-note:</i> Correct selection of timber, and design.	
II. SEASONING.	Practice of air-seasoning and kiln-drying; kiln design.
<i>Key-note:</i> Reduction of waste in seasoning.	
III. TIMBER PHYSICS.	Scientific study of the relations of water and heat to wood; physical chemistry.
<i>Key-note:</i> Basic principles of seasoning.	
IV. WOOD TECHNOLOGY.	Anatomical features in relation to uses; identification (in co-operation with Imperial Forestry Institute, Oxford).
<i>Key-note:</i> Correct choice of species.	
V. PATHOLOGY.	Fungi and insects causing decay; toxicity of preservatives (in co-operation with Imperial Forestry Institute, Oxford, and Imperial College, London).
<i>Key-note:</i> Causes of decay.	
VI. WOOD PRESERVATION.	Commercially practicable methods of treating timber with anti-septics; cheapening the cost.
<i>Key-note:</i> Reduction of waste from decay.	
VII. UTILIZATION.	Study of industrial methods in order to ensure the practical character of research and the advice offered. Investigations leading to new uses and markets for home- and Empire-grown timbers.
<i>Key-note:</i> Liaison with industry.	

VIII. WOOD-WORKING.

Machining and finishing qualities and effects of treatment (e. g. degrees of seasoning) thereon.

Key-note : Practical wood-working.

IX. CHEMISTRY OF WOOD.

Constitution; changes under various treatments (e. g. seasoning), cellulose products, including those from waste wood (e. g. from sawdust). (In co-operation with St. Andrews University.)

Key-note : Knowledge of wood-substance.

Note : At a later date it may be necessary to form, and include this work in, a Section of Minor Forest Products to deal also with extractives (tannins, resins, gums, &c.), destructive distillation, pulp and paper, and fibres.

X. PERMANENT RECORDS AND LIBRARY. Recording and issue of information: reference library.

Key-note : Ready and up-to-date information both to research workers and the trade.

A brief account of some of the problems that have been undertaken during the past year, and the means by which they have been investigated, will serve to illustrate the kind of service that the Laboratory hopes to do.

One of the first investigations to be put in hand concerns the utilization of home-grown species for pit-props. This inquiry involves the testing by the Section of Timber Mechanics of a large number of native props, half when in the green condition as felled and half when air-seasoned, with similar tests for comparative purposes on props from various foreign sources, the tests being carried out by crushing in a 200,000 lb. hydraulic multi-lever Universal Testing Machine. The results give the comparative strength and character of failure that may be expected of the species in pit-prop dimensions for stated qualities of timber. The home-grown species tested to date in the green condition include Scots and Corsican pines, larch, Norway spruce, and Douglas fir, while the foreign species so tested include Scots pine and Norway spruce from Norway, Sweden, Finland, Poland, and Russia. Tests on the air-dry material are now in progress. Complementary tests by the Section of Seasoning are being made in various localities in England, Scotland, and Wales, where sample piles have been set up to ascertain the best methods of stacking the props so that they shall season in the shortest possible time with due regard to freedom from defects due to quick drying. At the same time studies are in progress by the Section of Utilization regarding the requirements and conditions of use in the various mining districts, the question of grading and marketing the props, and cost of material and transport. Finally, the Forestry Commission, in co-operation with whom this investigation is being carried out, have arranged with certain mines to try out sample consignments of these home-grown props, each of which will be marked and registered and, as it becomes unserviceable, will be returned to the Laboratory for examination.

The testing of pit-props corresponds more nearly to the testing of structural

timbers, in which account is taken of the influence of defects, a side of timber-testing which the Laboratory has not yet taken up. In preparation for this branch of the work, a species is first tested for what is called its inherent fibre-strength. These tests are done on small samples free from defects and they give a measure of the optimum strength of the species in compression, bending, and so forth. Up to date, Scots and Corsican pine, larch, Douglas fir, and ash from certain districts have been tested in this way, to be followed by oak, all in the green condition. Tests on the air-seasoned material will follow when this is available. It should perhaps be explained that tests on green material are made because the amount of water in wood, less or more, over a certain percentage has no influence on the strength. But when once the free moisture contained in the wood-cell cavities has disappeared, and when the moisture held within the substance of the fibre itself begins to dry out, then most of the strength values increase the drier the wood becomes. Thus the tests that are made on green material yield results that are more truly comparable, since the material in a green state is unaffected by the variations in fibre conditions brought about by seasoning. The kind of test just mentioned, on material free from defects, provides a standard of optimum strength against which may be compared the results of tests made on large-size timbers containing defects, and is used to determine the influence of rate of growth, density, and moisture content. In order to obtain reliable average figures, in dealing with the considerable variation in strength that occurs in wood even in samples from the same tree, a great number of samples must be tested, taken from trees grown in different localities and under various conditions of soil, climate, and other factors. In the present series of tests on ash, for instance, which deal with nine trees from one locality, 1,114 mechanical tests have been made and 1,699 complementary physical tests, with about the same numbers still to be carried out on seasoned specimens. It is proposed that the results of tests on oak shall be regarded as the datum line in comparing the strengths of British timbers. The tests as carried out at the Laboratory are susceptible of comparison with those of the Laboratories of the United States, India, Canada, South Africa, and New Zealand, all of which have adopted as standard practice the use of the machines and methods of test proposed by the American Laboratory, who were pioneers in this and other fields of investigation in forest products and to whom a debt of gratitude is owed for the assistance they have so willingly and courteously given to other Laboratories in course of formation.

The Section of Seasoning carries out studies on both natural and artificial seasoning. In artificial seasoning the experimental plant consists of three kilns of semi-commercial size, respectively of the water-spray, internal fan, and external blower types, with two small 'model' kilns as an adjunct. The work concerns kiln design, and the various means of producing a circulation of air and of regulating and recording humidity and temperature conditions in the kiln, the provision of drying schedules for various classes of timbers, conditioning, steaming, and sterilization against fungi and insects. An increasingly considerable amount of advisory work is also being undertaken. In connexion with air-seasoning, the Laboratory is co-operating with the furniture trade in an investigation, by means of small samples of various woods finished in various ways, placed in different localities and different positions inside the house, to discover the proper moisture-content that furniture should possess for use in particular

situations. In the field of kiln-drying, experiments have been made with native Scots pine, oak, and Corsican pine (cut to a specification for cottage construction); with teak panelling for a railway company, British Columbia western hemlock, and British Columbia Sitka spruce for use as aircraft timber. An experiment with ash for an omnibus construction company is in progress, having for its object the comparison of the respective merits of air-dried and kiln-dried material.

The Section of Timber Physics deals with the basic sciences of seasoning, in studying the way in which moisture moves through the wood in drying; the laws governing this movement and its rate; the hygroscopic power of wood with reference to shrinking and swelling; heat and electrical conductivity, and the like. The subjects falling to this section have been very little studied and form an important branch of the Laboratory's work.

The Section of Wood Technology is concerned with the identification of timbers and with the study of their anatomical structure in its relation to their physical and mechanical properties. One of the main lines of work consists, therefore, in indicating woods which, having similar characteristics, are likely to form efficient substitutes for other woods which are either becoming scarce or, being of foreign origin, might be replaced by an Empire product. The suggestions of the Section would be referred to Timber Mechanics for mechanical tests, Seasoning for determination of seasoning characteristics, Wood-working for machining and finishing qualities, and to Utilization on questions of availability of supply and costs. In connexion with the strength tests on ash, the Section of Wood Technology is concerned with that side of the investigation which concerns 'brashness' or short grain in timber, in so far as this may be due to structure. Another study is concerned with the differing working qualities found in oak timber, as for instance the mild, easily worked oak that comes from the Volhynian district of Austria and the strong hard oak, difficult to work, that is typical of the British product.

Owing to the limited accommodation at Farnborough, it has not yet been possible to carry out any investigations in the direction of practical wood-preservation, but an up-to-date experimental plant is being installed at Princes Risborough, and work should be begun during the summer. Studies will be made of the various methods of preservation, using creosote, water-soluble salts, mixtures of the two, mixtures of crude oil and creosote, and so forth, and one of the primary aims will be to cheapen the process and thus increase its use. Considerable work has, however, been done by the cognate Sections of Mycology and Entomology in the laboratory study of fungi and insects causing decay, including also the study of antiseptics. One very important investigation by the Section of Entomology is nearing completion, namely, the question of the losses caused by the *Lyctus* beetle in yard timber used in furniture-making. In co-operation with the Section of Seasoning a kiln treatment has been developed, using a model-size kiln, which promises to offer a practical solution of the trouble, and only needs confirmation of its efficiency by trial in one of the Laboratory's full-sized kilns.

The Section of Utilization includes a large and varied field of work. Acting as the liaison between the Laboratory and industry, one of its principal duties is to translate the results obtained by the Laboratory into commercial terms. Members of the Section are constantly visiting various industries, giving and

receiving information, which not only helps to spread knowledge but keeps the work of the Laboratory running on practical lines. The work has developed very rapidly, and a large number of inquiries have been dealt with concerning the uses, market values, grading, supplies, and costs of various timbers. Primarily the objects aimed at by the Section are the promotion of the use of home- and Empire-grown timbers in lieu of foreign supplies, and a more efficient utilization of timber and other forest products. By way of illustration may be mentioned the possible substitution of American hickory, used for railway shunting poles, by an Empire-grown timber. The results of mechanical tests of one such timber were sufficiently promising to warrant the Section of Utilization arranging with a railway to place an order for a sample shipment of twenty-five tons of the timber, to be made up into shunting poles and tested under actual working conditions on the railway. Another project of a different type concerns the means of marketing and utilizing undersized oak, of which there is a very large acreage in this country.

The Section of Wood Chemistry has not yet been fully developed. The Laboratory has one worker carrying out research at St Andrews University, and it is hoped to extend this activity as means permit. Comparatively little attention has been paid to this subject, fundamental though it is, and it bristles with difficulties.

Lastly, considerable progress has been made by the Section of Permanent Records in the assembly and classification of information and in building up a technical library. Much depends on the efficiency of this Section, both in keeping the Laboratory staff abreast of the latest information and in placing it quickly before outside inquirers.

Broadly speaking, a successful research falls into three stages, these being laboratory tests, large-scale tests, and tests on a commercial scale to prove the economic soundness of the results. In all three stages the forester, the Laboratory, and the industry must work in partnership. The success of the Laboratory as a national institution depends on the hearty co-operation of all these interests, alike in setting research on foot, in affording information and assistance during its progress, and in promoting the general application of its results.

AESTHETIC CONSIDERATIONS IN BRITISH FORESTRY

BY W. DALLIMORE

FRILLS are unnecessary but very pleasing and interesting additions to the normal round of daily life. The sweet young lady can live her life and attain a ripe old age even though wearing the plainest of attire; the dashing young man cannot add a day to his life by wearing bright purple or green socks and elaborate neckties; the letters K.C.M.G., or K.C.B., after the name of a State worker, do not arrest the steps of the death angel; whereas buildings might be erected far more cheaply and be just as durable on the old barrack-system plan, than they are when built after the designs of eminent architects. But what a drab world it would be. We should save money, but imagine every young lady dressed with quakerish simplicity in sad-coloured garments; our young men spatless, wearing dark grey socks and black neckties; our admirals and generals without their decorations, and our streets and squares lined with gaunt, all alike walls with all alike doors and windows. All this applies to silviculture with just as much force as to other objects. In order to produce good timber and the maximum volume per acre aesthetic considerations need not be studied. Simply form blocks of trees with harsh and well-defined boundary lines, and they will be cheaper to maintain than blocks with irregular margins and probably there will be less waste timber. Moreover there is no need to worry about the sombre appearance of huge blocks of pines, the timber at maturity may be worth a penny a foot more than the timber of some brighter hued tree, therefore get all that is possible from the ground; as some would have us understand it, that is the correct system of silvicultural management. But think again what a dismal prospect would be created. Fancy block after block of the same kind of tree, the trees spaced with mathematical accuracy, and only relieved by other blocks of another kind of dismal uninteresting tree that can be only looked upon as representing so many pounds, shillings, and pence.

On the other hand consider a section of our unspoiled country-side. Foreigners always admire the landscapes of the British Isles. So many of these landscape scenes are of the open park-like type, or, where dense woods appear, they are gradually led up to by tree-dotted fields and commons which effectively mask any harshness that may be present about the outlines of the woods. Then the great variety of trees seen in our landscapes is conducive both to interest and beauty. Even in winter, when many trees are leafless, they still make a strong appeal. The silver bark of the birch, the grey of beech and hornbeam, the yellow and red of some of the willows, the catkins of willow, alder, and hazel and a dozen other items all call for attention. Later, when young leaves appear, the many shades of green contrasted in several instances by attractive flowers or later still by bright fruits, the country-side is seen in other clothing; and then the wonderful colouring of trees such as the beech and elm in autumn makes a long journey to some favourite spot inevitable. This is the country-side which we should aim at maintaining in our silvicultural efforts. A forest area may bring in a somewhat lower return if attention be paid to aesthetic considerations, but fancy what is gained indirectly by the pleasure afforded to the community. Few people can remain unaffected by beautiful surroundings, and a peaceful country-side where agriculture and silviculture join hands can

be peculiarly attractive. There is, however, a tendency in some places to divorce the occupations by the removal of all trees from farm-land. May the time be far distant when this becomes a habit in the British Isles.

People who are making extensive plantations of trees can, by a little thought, maintain much of the landscape beauty of the British Isles. They can aim at informal outlines with the dense forest merging naturally by groups and isolated trees into farm-land; they can plant about the borders of their woods and forests groups of attractive and interesting trees or large shrubs, and where vantage points occur they can introduce groups of brighter coloured trees amongst those of sombre hue. But in selecting trees for such plantings they must be careful to use only British trees or shrubs, or such exotics as will group naturally with British species. Variegated-leaved plants must upon no account be planted amidst natural surroundings; neither should trees that are palpably garden trees. There are hardy trees and shrubs that are quite at home on the margins of woods, as, for instance, the spindle tree, the wayfaring tree, white beam, mountain ash, guelder rose, dogwood, sloe, crab-apple, cherry, hawthorn, and many others. Where rhododendrons are used, it is better to plant those bearing white or mauve flowers than the reds or other bright shades. Farmers should be encouraged to allow certain trees, particularly hedgerow trees, to remain, and as one is taken out another should be put in. Even dwarf, scrubby trees growing on commons and bare hill-sides have their place in the landscape. Possibly nothing larger would grow where they exist; they are often picturesque, and, although they do not appeal to the commercial man, their artistic value is often very great. It is the same with cliffs and more or less bare rocks, whenever tree or shrub life can be established the position becomes more picturesque and interesting; therefore, while considering the commercial aspects of forestry there are excellent reasons why the aesthetic side should not be forgotten.

A word of warning may be permitted in another direction. In the desire to obtain the maximum revenue from the country-side, owners of vantage points in agricultural land allow, for financial considerations, hideous advertisements to be erected. Whilst it may be an act of grace for vendors of patent medicines and fancy soaps to keep people constantly informed as to the respective merits of rival productions, all true lovers of Nature trust that it will be a very long time before silviculturists adopt such a scheme as a source of revenue.

A GENERAL REVIEW OF POST-WAR FORESTRY IN CENTRAL EUROPE

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PART I

THE War and its consequences have changed Central Europe in many important points. Forestry, being a well-developed and most essential part of the economic life in the respective countries, naturally could not escape the great transformations which have taken place. The forestry of Germany and the old Austrian Monarchy with which this article deals was changed in many respects from the very foundations. Of course, only a general view on all these new transformations can be given and it would be the task of special articles to go deeper into these interesting problems.

Taking a bird's-eye view, we see that these changes fall into two categories which can be clearly distinguished, although they frequently influence each other. They are, first, the development in matters of forest policy, and, secondly, changes in all that is comprised in silviculture, forest management and forest economics.

The redrawing of the map of Central Europe created a completely new *status quo* in forestry, and the great alterations in the state of political power and influence in the respective countries have naturally caused also a revision of all important questions of forest policy. So far as these new tendencies are the results of purely political conditions only, their influence on progress in forestry is a varying one, on the one hand beneficial and on the other retrograde.

But the new tendencies in silviculture, forest management and forest economics, are deeply rooted in the unique post-war conditions, not only of the political but also of the economical life in Central Europe. The principal features of this period are universal impoverishment and the absolute necessity for economizing in all raw materials, and this has exerted an influence on all the main principles of practical silviculture and forest management in the direction of increasing, as much as possible, the intensity and efficiency of forestry.

Immediately after the War it appeared that forest policy and political conditions were the two items which required most urgent revision. Later on, however, the problems of reform in silviculture and management came more and more to the front and the problem of increasing the productivity of forestry became dominant. These two directions of evolution can be clearly distinguished in the German countries, whereas in other countries, e.g. Czechoslovakia, political reforms have so far remained the dominant interest.

There are many reasons why we must always take the corresponding conditions of the pre-war period into consideration whilst describing the post-war conditions. First, we cannot illustrate clearly all the changes which took place, unless we compare the present state of things with what went before. Secondly, many of the now leading tendencies have their beginning far back in the time before the War. Further, we should not neglect the results of many exact investigations carried out and the statistics collected in the calm, peaceful atmosphere before the War.

The world's timber trade started approximately in the year 1860 as the result of the increasing need of timber in the countries of western Europe,

namely, Great Britain and Germany. These countries could not meet their timber requirements from their own production and stretched out their hands towards the vast forest resources in northern and eastern Europe. Germany began to import timber in 1864 when its increasing population and industry found the home timber production insufficient. The direction of timber trade in Europe runs from north to south, from east to west. The following pre-war figures will illustrate this movement:

<i>Annual Timber Exports in Europe.</i>					<i>Annual Timber Imports in Europe.</i>				
Russia . . .	17·00	million cubic metres ²			Great Britain	29·00	million cubic metres		
Finland . . .	9·50	"	"	"	Germany . .	12·80	"	"	"
Sweden . . .	15·00	"	"	"	Italy . . .	5·00	"	"	"
Norway . . .	3·30	"	"	"	France . . .	3·10	"	"	"
Austria-Hungary .	8·00	"	"	"	Spain . . .	1·00	"	"	"
Rumania . . .	0·70	"	"	"	Switzerland .	0·80	"	"	"
<i>Total</i> . . .	53·50	"	"	"	<i>Total</i> . . .	51·70	"	"	"

There are, however, notable differences between the various timber-importing countries. Some of them have only a very small forest area and hence an unimportant timber production, e. g. Britain and Holland. Some have undeveloped forest resources, e. g. Italy, Spain, Greece and Portugal; others have great forest resources, but the means of transport are primitive, e. g. Bulgaria. Finally, some of these timber-importing countries have great forests and well-developed systems of forestry, but, in spite of this, an insufficient timber production. Amongst these last, there are France, Switzerland, and particularly Germany.

Out of the total land area of Germany, which amounted in 1913 to 54,109,836 ha.,² the forest land formed 26·29 per cent. or 14,221,172 ha. This represented 0·22 ha. per head of population. The southern parts of Germany are relatively richest in forest. The total annual wood-harvest amounted in the year 1913 to:

	28,663,648	cubic metres timber.
	19,208,608	" " firewood.
	10,605,017	" " branchwood and stumps.
<i>Total</i>	58,477,273	" " or 4·11 c. m. per ha.

These figures represent the highest sustained forest-production per ha. in the whole of Europe.

In spite of this very high forest-production Germany was compelled to import in the years 1907-13 approximately 14 million cubic metres of timber per annum, because in the time immediately before the War the annual requirements, due to the increasing population and industry, amounted to 40 million cubic metres.

The whole development of German timber importation is directly correlated with increasing population, as can be seen by the following figures.

The annual timber importation was:

1879-1884	2·67	million cubic metres.
1885-1887	3·73	" " "
1888-1896	5·86	" " "
1897-1901	9·32	" " "
1902-1906	10·74	" " "
1907-1913	14·23	" " "

² 1 cubic metre = 35·32 cubic feet.

² 1 hectare = 2·47 acres.

In the same time the population increased from 45·23 million to 64·93 million inhabitants. The deficit in forest-production was still further increased by the loss of the 2·6 million hectares of forest which Germany has lost in consequence of the Treaty of Versailles. This area represents an annual timber-production of 3·8 million cubic metres, not counting the firewood, branchwood, and stumps. Besides this Germany lost in the Cameroons about 15 million hectares of tropical forest, in East Africa $3\frac{3}{4}$ millions, of which one million was high forest, and in Togoland $\frac{3}{4}$ million hectares. The extent of the forests in the lost colonies of the Pacific Ocean are not known.

This important loss of forest area has directed attention to the overhauling of the principles of practical forestry with the aim, if possible, of increasing forest-production.

The foundation of German forestry rests on the excellently managed State forests. They are the very backbone of German forest-production. Their area forms only 34·7 per cent. of the total forest area, but they produce 50·8 per cent. of all home-grown timber. Up till 1908 only moderate fellings were carried out in the State forests. In that year a motion was brought forward by Count Toerring in the Bavarian Chamber to increase the fellings in government forests and this sound proposal was accepted. Toerring's idea spread to other German States and during the period 1908-13 many old over-mature crops were regenerated.

In 1913 communal forests formed 16·1 per cent. of the total forest area, but they contribute only 13·6 per cent. to the home timber-production. These forests are to a large extent broad-leaved forests managed as coppice or coppice-with-standards. In many cases also the communes make too large demands upon their forests, e. g. by removal of litter, &c.

Far better managed are the forests held by different corporations, forming 1·6 per cent. of the total forest area. The management is controlled by the State.

Of the private forests which form 45·5 per cent. of the country's forest area, 11·8 per cent. are entailed and 33·7 per cent. are free. The entailed forests are very well managed and come in this respect very near to the State forests. They produce 14·4 per cent. of the home-grown timber. The management in the free private forests is not so good, as a large number of them belong to small landowners, and forestry, in this case, is often regarded only as an adjunct to agriculture.

Out of the whole forest area roughly 30 per cent. are broad-leaved and 70 per cent. coniferous woods. The percentage of broad-leaved species is highest in the forests belonging to the communes. For more than 100 years the conversion of broad-leaved forests into coniferous ones has been going on, and since about 1883 this tendency has increased. There are many reasons for this, the most important being the relatively greater production of timber given by conifers in shorter rotations. From the point of view of timber importation this conversion of broad-leaved forests may be regarded as useful, since 90 per cent. of the imported timber is coniferous. The 10° E. meridian of longitude separates roughly the eastern coniferous area from the western broad-leaved region in Germany.

Amongst the broad-leaved species oak and beech are the most important. The total area of oak forests amounts to 633,300 ha. On a rotation of 160 years,

the normal area of oak crops over 100 years old should be 248,700 ha. Actually this area amounts to 122,500 ha. only. This deficit in old oak woods will certainly bring a restriction of fellings in future. The reason of this deficit is the comparatively small regeneration of oak during the period between 1793 and 1813 due to wars, financial crises, and different disorders in that time. Different silvicultural mistakes are also, in part, responsible. After this time the creation of oak forests increased and reached its highest point between 1873 and 1893.

We find just the contrary amongst the beech crops. The creation of beech forest came to its height between 1820 and 1850. This was the final result of working with a view to producing firewood, which was the leading aim of forestry for many centuries, natural regeneration of beech crops for this purpose being regarded as of prime importance. From about 1840 coal began to displace firewood and the creation of beech crops became less important. The following proportional figures show this diminution in regeneration of beech.

1833-1853	100
1853-1873	79
1873-1893	68
1893-1913	51

Prussia is richest in Scots pine, while spruce prevails in Bavaria, Württemberg, and Saxony. In the western parts of Germany spruce was introduced artificially except in the Hartz Mountains, where spruce is indigenous. There is a preponderance of the young-age classes, often the result of conversion from broad-leaved to coniferous woods, spruce being the principal species used. Silver fir is indigenous to the Vosges, the Black Forest, the Frankenwald and the Bayrischer Wald.

The different methods of treatment are given by the following figures:

Broad-leaved woods 29.9 per cent.	{ 5.1 per cent. coppice forests,
	{ 3.8 per cent. coppice-with-standards,
	{ 2.4 per cent. shelterwood selection system,
	{ 18.6 per cent. other shelterwood systems and clear-cutting system.
Coniferous woods 70.1 per cent.	{ 7.7 per cent. shelterwood selection system,
	{ 62.4 per cent. other shelterwood systems and clear-cutting system.

The outbreak of the revolution in the year 1918 gave rise to the idea of nationalizing the forests, and the different parties used this idea for their own political purposes.

It is not to be wondered at that forestry was taken up as a good subject for different schemes of expropriation, since many arguments may be legitimately urged in favour of it. In Hessen, for example, a motion was brought forward in the year 1920 with the view of sequestering all private forests, and more or less similar proposals were made elsewhere also.

But after all, Germany has maintained, in general, a considered attitude on these questions, compared with other countries. The new German constitution of the 11th August 1919 confirmed the security of private property, and only permitted certain expropriations in the public interest with compensation. No nationalization of private forests took place and attention was concentrated

on an intelligent encouragement of the development of private forest management. Such a moderate tendency is shown, for example, in a publication issued by the Forest Council of Germany ('Reichsforstwirtschaftsrat'). It was admitted that private forestry has great importance and should be preserved, and that the returns from State forests are in many cases not satisfactory at all, in spite of efficient forest management from the technical point of view. Amongst Government forest officers a high sense of duty is common, but there is not the same progressive and vigorous policy in State control, which is necessary for a renaissance in forestry. A certain control by the State, the formation of forest co-operative societies, the limitation of fellings, afforestation by statute, the commutation of servitudes, the development of forest education and the propagation of knowledge, and the organization of professional forest societies were considered to be the best means of helping development in private forestry.

Private forestry in Germany until now has been free or only in a mild way controlled by government. However, there are some local differences. In the southern parts of the country government control took place much earlier and in a stronger form. The population was accustomed to it and this helped in its further development. In the north, private property and freedom to deal with it was more deep-rooted, and practically no forest control existed.

After the War several new proposals were made, aiming at a greater control of private forestry. One of the most important of these was the drafting of a new forest law in 1920 for the whole country. This aims at a careful and economical management in private forests, but does not interfere with private interests. Only negligent forest owners will be affected by it. The principal features of this law are as follows: The government is empowered to ask for all the important figures regarding the forest management of private forests, such as area, species, proportion of age classes, yields per ha., &c. Above a certain size, all private forests are bound to prepare working plans, forests under this size may prepare a short report only. Fellings are permitted only if special licence is given. The government is entitled to insist that land which has been cleared of forest without weighty reasons and also suitable bare land should be afforested. Cleared areas should be afforested within three years. Small forests which could only be managed by co-operative societies should be brought together into such corporations. The division of forests into small areas is not allowed. The creation of forest servitudes concerned with forest utilization, or even the extension of existing servitudes of this kind, is prohibited. All private forests should have the advice of experts. The law gives also a guarantee of sustained forestry. Another example of such tendencies in forest policy is the draft for a forest law in Prussia of November 1920. This law also provides for certain control of private forestry by the government, the formation of forest co-operatives societies, the conditional prohibition of fellings, &c. Another draft of the 10th December 1920 lays down that all feelings overstepping 1/60th of the whole forest area require a special licence before being carried out.

Of course a development of and renaissance in private forestry should be helped in the first place by the private forest-owners themselves. To this end different societies of forest-owners were formed in Germany before the War, and they are now joined together in one great union. To give a more detailed account of the organization and the important work of these societies would overstep the limits of this article.

One of the most important features in the forest policy of Germany and of the whole of Central Europe is the abolition of entails which is provided for in Germany by the constitution of the 11th August 1919. The antipathy against this kind of private property is long-standing. In France the abolition of entails took place in the year 1792, and in Germany a motion was brought forward in parliament before the War, aiming at abolition. During the War different landowners hastily enlarged their entailed property by which the existing antipathy was increased. From the standpoint of forestry the entails brought many advantages; e. g. the intimate relation of the private owner to his land was increased further by tradition. The restrictions in property and utilization resulted in good management. The advantage of government forestry and those of private forestry were combined in this form of property. Entailed forests formed the very backbone of private forestry and splendid examples of forest management can be studied in many entailed private forests in Central Europe, e. g. in Bohemia and Czechoslovakia. These notable advantages were acknowledged in Germany, also, after the revolution, and several provinces have started institutions which aim at the preservation of these advantages, but also take into account modern social views. These institutions are, for example, the so-called 'Waldgüter' or 'Waldstiftungen' in Prussia, Würtemberg, Baden, and other States.

Immediately after the War a great demand for arable land arose. It was pointed out that a large number of forests occupy land which would be suitable for agriculture also, and that it would be a mistake to carry on forestry on soils which were suitable for agriculture or industry. The timber demand could be satisfied by importation from Sweden and Finland. To obtain land for small peasants, private forests should be expropriated. The Ministry for Finance in Saxony ordered in 1920 enlarged clear fellings with the idea that the stumps on cleared ground should be uprooted and the land given up to agriculture. This trial has not been successful owing, among other reasons, to the high cost of removing the stumps.

In this question of procuring land for inner colonization, Germany has also kept a deliberate attitude. No forests were sacrificed to a momentary land famine. One can easily destroy forests, but it takes much trouble, requires a long time, and costs much money to build them up again.

The general view on this subject now is that the granting of the licence, permitting the uprooting of trees, should be decided by the relative suitability of the land for agriculture or for forestry.

The total area of Germany before the War was 54 million ha. Of this area 34 million hectares were occupied by agriculture and 14 million by forestry. Neither area was sufficient for the respective wants of the German population. A transference of area from one branch to the other would bring down the production of the one, without increasing it in the other to the required scale, thus providing no real remedy. At the same time it cannot be denied that chance, as well as economic suitability, enters into the present distribution of land between forestry and agriculture in Germany. Typical forest soil is occupied here and there by agriculture, whereas soils fit for agriculture are covered in some cases with forests. A state of things undoubtedly disadvantageous to national economy can easily be corrected by clearance, or by afforestation respectively, but an absolute prohibition of clearance would not do good.

Further, this subject should be viewed from the standpoint of increasing population. Before the War large landowners bought up tenements, farms, or even whole villages and afforested the land on a large scale. The reason was chiefly the safe investment which forestry gives. Fortunes gained quickly were invested in this way. Between 1878 and 1913 the area occupied in Germany by agriculture decreased by 1,912,000 hectares against which forest area increased by 348,246 hectares. This means an annual increase of forest area by 10,000 hectares, which certainly seems to prove that afforestation is under certain circumstances not a bad investment. To buy up farms and to afforest land on a big scale is now usually prohibited by law in Germany.

Quite a different question, of course, is the afforestation of barren soils. This is a great and most important problem of national economy and great attention has been paid to it in Central Europe. However, in the year 1900 there were 633,303 hectares of barren land fit for afforestation in Germany.

During the War also the subject of combining field crops with forestry was taken up again. The result was not promising, owing chiefly to the lack of workmen. From the standpoint of silviculture this method of management, however, is undoubtedly advantageous because of the loosening of the soil and the enlarging of the agricultural area. Before the War, however, the combination of field crops with forestry did not usually pay.

(To be continued)

SOME RECENT FOREST RESEARCH IN NORWAY

BY ERLING EIDE

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1. THE REGENERATION OF THE PINE FORESTS IN NORTHERN NORWAY.

SINCE the forests of Scots pine (*Pinus sylvestris*) in the northern districts of Norway were taken over by the administration of the Forest Service about 1860, the most difficult problem to solve has been the regeneration of these forests. Hagem (1) has studied this problem and found that the temperature in summer (June–September) is only exceptionally sufficient for the ripening of seed. He concludes that a summer temperature of 10.5° C. is necessary for the production of good seed (i.e. seed giving 50 per cent. of plants in the nursery). The significance of this temperature limit is confirmed by the investigations of the Institute of Experimental Forestry (2), based on data from a series of provisional meteorological stations in the forest districts, combined with seed studies. Further investigations in the seed-year 1923 (3) have shown that the weather conditions during the flowering season are exceedingly important for the seed quality. When these weather conditions are favourable, the quality will depend on the temperature of the next summer (the ripening season). This northern seed is usually characterized by a low percentage of germination, but the plant percentage is, in proportion to the germination power, considerably higher than that of the pine from southern districts. A remarkable feature is its ability of resting in the soil for one or two years before germination (4).

In 1925 Juul published an important memoir on the former and present extension of the pine forests in northern Norway. He confirms that a great decline in the forests has taken place, and asserts that the limits of the pine forests are situated above the present climatic limit of this species of tree. The decline must consequently be considered to be the still lasting effect of a change of climate far back in the past. Further, he considers that the extinction of the pine forests in the inner districts must be due to other causes than in the coast districts. In the interior of the country the low summer temperature only gives rise to seed-years at intervals of fifty years or more. In the coast districts the seed production is better, but an extensive development of raw humus seems to prevent the regeneration of the pine.

- (1) Oscar Hagem: 'Furuens og granens frøsetning i Norge' ('The Seed Production of Pine and Spruce in Norway'). *Meddelelse nr. 2 fra Vestlandets forstlige forskningsstation*, Bergen, 1917.
- (2) Erling Eide: 'Om temperaturmaalinger og frøsetning i Nord-Norges furuskoger' ('On Summer Temperature and Seed Production in the Pine Forests of Northern Norway' [with German summary]). *Meddelelser fra det norske skogforsøksvesen*, h. 3, Oslo, 1923.
- (3) —: 'Undersøkelser av norsk furufrø fra modningsaaret 1923' ('Investigations of Norwegian Pine Seed from the Seed Year 1923'). *Meddelelser fra det norske skogforsøksvesen*, h. 5, Oslo, 1925.
- (4) —: 'Om saaforsøk med nordnorsk furufrø' ('On Sowing Experiments with Pine Seed of Northern Norway'). *Meddelelser fra det norske skogforsøksvesen*, h. 5, Oslo, 1925.
- (5) J. G. Juul: 'Furuens utbredelse i Finnmark og Troms' ('The Extension of Pine Forests in Finnmark and Troms'). *Tidsskrift for Skogbruk*, 1925.

2. THE RELATION BETWEEN GROWTH AND CONSUMPTION IN NORWEGIAN FORESTRY.

During the last three centuries several official commissions have stated that the cutting in Norwegian forests far exceeded the annual growth, and that future lack of timber must be considered a threatening danger. This danger has been prevented up to now, because the commercial idea of 'wood' has gradually changed from signifying masts and balks to include, in our days, the smallest sticks which may be used in the pulp industry. Judged from the standard of the seventeenth century, the Norway of to-day is in reality almost without forests, and yet the export of timber and other forest products amounts to about 35 per cent. of the total export value.

The increasing importance of the forests has made the question of the balance of forest increment and consumption the most burning questions of Norwegian political economy. In 1916 Barth published an article (1) in which he tried, by the help of careful estimates, to prove that the Norwegian forests were going rapidly to ruin. He calculated the annual increment to be only 9,700,000 cubic metres¹ and the annual consumption to be 12,516,130 c. m.

Barth's calculation produced much opposition, but undoubtedly his article led the Storting to decide on a general measurement of the Norwegian forests. Since 1919 the Landsskogtakseringen has been engaged in the large task of fixing the increment and cut in the forests, while at the same time the Central Bureau of Statistics is working out the statement of home consumption and exportation. The Landsskogtakseringen makes use of the line-survey method, separately for each county, the distance between the lines varying from 2.5 to 8 kilometres,² according to the size of the county. Up to the present day the investigation of seven counties has been completed. The results are treated in a mathematico-statistical way, for which Langsæter (3) has developed the most reliable method.

For the seven counties the main results are summed up as follows:

Productive forest area . . .	3,948,266 hectares ³
Total volume . . .	177,790,100 cubic metres
Total annual increment. . .	5,418,143 „
Volume per hectare . . .	45 „
Annual increment per hectare	1.37 „

These figures show that Norwegian forestry is maintaining a very small stock, and that a considerable increase of supply and increment must be possible in spite of the often unfavourable conditions of growth. Some counties are not yet dealt with, while the statement of domestic consumption is not published. The main question, whether the production and the consumption are balanced, cannot yet be determined. The preliminary results show that the annual increment per hectare will scarcely reach the quantity supposed by Barth. On the other hand, the forest area appears to be larger than formerly believed, and the home consumption seems to be smaller than the calculation of Barth.

It is to be hoped that the result of the measurement will make clear to the

¹ 1 cubic metre = 35.32 cubic feet.

² 1 kilometre = 0.62 miles.

³ 1 hectare = 2.47 acres.

Norwegian people that the yield of the forests is far from corresponding to what it should be.

- (1) Agnar Barth: 'Norges skoger med stormskridt mot undergangen' ('Are the Forests of Norway rapidly going to ruin?'). *Tidsskrift for Skogbruk*, 1916.
- (2) Landsskogtakseringen: *Taksering av Norges skoger*, i-vii ('Mensuration of the Norwegian Forests,' i-vii), Oslo, 1920-7.
- (3) A. Langsæter: 'Om beregning av middelfeilen ved regelmessige linjetakseringer' ('On the Calculation of the Mean Error in the Results of a Line-Survey'). *Meddelelser fra det norske skogforsøksvesen*, h. 7, Oslo, 1926.

3. INVESTIGATIONS ON THE FORM OF TREES.

In order to provide reliable volume tables the author has studied the problem of tree form, especially of the Norway spruce. According to these studies the author states that the form-factor for every normal type of spruce stand is only dependent on the relation between height and diameter (at breast height). This relation is a very simple one and may be expressed in the following equation:

$$f = 0.650 - \frac{0.16 d - 0.40}{b},$$

or

$$fb = 0.40 + 0.65 b - 0.16 d.^1$$

Material for the investigations has been obtained from the sample-plots of the Institute of Experimental Forestry, representing fifty-three stands and including the largest variations obtainable as to age, soil quality, density, and climatic conditions. The correlation between height and form-factor within various diameter-classes were determined to be:

Diameter 15 cm. ²	r = +0.906 ± 0.025
„ 20 „	r = +0.917 ± 0.023
„ 25 „	r = +0.935 ± 0.022
„ 30 „	r = +0.925 ± 0.026
„ 35 „	r = +0.963 ± 0.020
„ 40 „	r = +0.989 ± 0.008

The principal results of the investigations are as follows:

- I. The form-factor increases with increasing height.
- II. The form-factor decreases with increasing diameter.
- III. The age does not influence the form-factor.
- IV. The density only influences the form-factor in the same degree as it may influence the relation between diameter and height.
- V. The quality of the soil does not seem to influence the form-factor, if it does not prevent a natural development of the trees. If the form-factor on unfertile soil is higher than on good soil it seems to indicate too close spacing in relation to the conditions of fertility in the soil.
- VI. The climate (latitude) only influences the form-factor in the same degree as the relation between height and diameter is influenced.
- VII. The form-factor follows the same equation in even-aged and uneven-aged stands.

¹ f = form-factor, b = height in metres, d = diameter at breast height under bark in centimetres.

² 1 centimetre = 0.3937 inch.

In order to illustrate the influence of height on the form-factor, I give some of the calculations:

Diameter 20 cm.	Height 14 m. ¹	Form-factor 0.450
" "	" 17 "	" 0.485
" "	" 20 "	" 0.510
" "	" 23 "	" 0.528
Diameter 40 cm.	Height 19 m.	Form-factor 0.334
" "	" 22 "	" 0.377
" "	" 25 "	" 0.410
" "	" 28 "	" 0.510
" "	" 31 "	" 0.456

These results show the relationship in growing stands, when the number of sample trees is sufficient to give reliable mean values for the calculated heights and form-factors. The equation seems to express a general rule of growth, where the conditions for the natural development of trees are present. Over-shadowed trees will gradually improve their form according as their normal height growth becomes depressed.

On single trees the method shows a mean variation of 30 to 40 form-factor units (one unit = $\frac{1}{1000}$).

Erling Eide: 'Kubering av staaende skog.' I. Furuskog ('Determination of the Volume of Growing Stands. I. Pine Forests'). *Meddelelser fra det norske skogforsøksvesen*, h. 3, Oslo, 1923.

II. Granskog (II. 'Spruce Forests'). *Ibid.*, h. 4, Oslo, 1923.

III. Fortsatte undersøkelser over formfaktorens avhengighet av høide og brysthøidediameter i granskog. (III. 'On the Relation between Form-factor, Height and Diameter in Spruce Forests'). *Ibid.*, h. 5, Oslo, 1925.

IV. Über den Formfaktor bei der Bestandesmassenermittlung ('On the Form-factor by the Measurement of Growing Stands'). *Ibid.*

V. Granens form innenfor bark ('The Form of the Spruce under the Bark'). (To be published 1927.)

4. ON THE FUNGAL PROBLEMS IN FORESTRY.

Few investigations of forest diseases have been made in Norway, especially of diseases caused by fungi. During the last few years the interest in these problems has increased. This is undoubtedly due to recent calamities which have overtaken the plantations of pine in the coast districts.

Jørstad (1) is engaged in the task of gathering and studying all data on previous fungi diseases and the summing up of our present knowledge of the various problems. The first part of this work deals with the diseases on conifers caused by Uredineae, Ascomycetes, &c.

Hagem (2) has made a study of the Lophodermium question. During the exceptionally cold and wet years 1921, 1922, and 1923, the pine forests of western Norway gradually became weakened, and the plantations lost their power of resistance to Lophodermium infection. It is established that the origin of seed is the most important factor in causing resistance. Plantations originating from the coast pine of western Norway did not suffer very much, while plantations originating from foreign seed, and even from Norwegian seed of the interior districts, suffered severely and sometimes were overcome by the disease.

¹ 1 metre = 3.28 feet.

Mork (3) has commenced the study of the favourable fungi, the mycorrhiza of the spruce roots. In the forest of Namdal, in latitude 64-5 North, it has been very difficult to obtain natural regeneration of the spruce, principally because of the luxuriant vegetation of herbs and ferns. Under the screen of a rather dense stand it is possible to get up young plants, but these plants are almost entirely growing on decaying wood from windfalls, stumps, and the like. Mork has found that these plants always and even from the first summer develop typical mycorrhiza. The reaction of the soil on the decaying wood is even more acid than that of the raw humus soil. The most probable reason why the plants are found on these special localities therefore seems to be that the decaying wood is favourable for the formation of mycorrhiza. These mycorrhiza are capable of transforming the humus substance into simplified compounds which can be utilized directly by the plants.

- (1) Ivar Jørstad: 'Norske skogsykdommer. I. Naaletresykdommer bevirket av rustsopper, ascomyceter og fungi imperfecti' ('Diseases caused by Uredineae, Ascomycetes and Fungi imperfecti on Conifers in Norway' [English Summary]). *Meddelelser fra det norske skogforsøksvesen*, h. 6, Oslo, 1926.
- (2) Oscar Hagem: 'Schütteskader paa furuen (*Pinus sylvestris*)' ('Lophodermium Diseases on Scots Pine'). *Meddelelse nr. 7 fra Vestlandets forstlige forsøksstation*, Bergen, 1926.
- (3) Elias Mork: 'Granskogens foryngelsesforhold i Namdalstraktene' ('On the Regeneration of the Spruce Forests in Namdal'). *Meddelelser fra det norske skogforsøksvesen*, h. 8, Oslo, 1927.

RECENT FOREST LITERATURE IN DENMARK

BY PROFESSOR CARL MAR: MØLLER

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MOST recent Danish forest literature is to be found in the *Reports of the Experimental Forestry Service in Denmark*, and in the two journals issued by the Danish Forest Society: *Dansk Skovforenings Tidsskrift* ('Journal of the Danish Forest Society', 500–700 pages a year), a quarterly containing the more scientific or purely technical contributions; and *Fra Skoven og Træmarkedet*, ('From the Forest and the Wood market', 200–300 pages a year), appearing every fortnight and giving room for discussions on current topics, news of different kinds, &c. Special articles dealing with the afforestation of heatherlands are to be found in the *Hedeselskabets Tidsskrift* ('Journal of the Danish Heath Society'). Only to a comparatively small extent are publications on forestry to be seen in other periodicals or as independent issues.

SOME EARLY FORESTRY WORK IN DENMARK.

As in most other countries, Danish silviculture was from the beginning much influenced from Germany. A German forester, v. Langen, was asked to come to Denmark in 1763 to improve our forestry and this influence has to some extent been continued until lately, though diminishing gradually.

About 1800 the great Danish statesman Count C. D. F. Reventlow commenced a new thinning treatment of his forests which even to-day would be considered very heavy, thus breaking severely with the German ideas of his time. By a number of measurements of trees he tried to prove that this method would give the highest increment per acre. From his estates the new treatment has gradually spread over the country, displacing the old German method of thinning.

The views of Count Reventlow are dealt with fully in his large work, *Forslag til en forbedret Skovdrift* ('Proposition of an improved Silviculture'), which was not published until 1879, many years after his death, which took place in 1827.

During the middle of the nineteenth century there was, relatively, a standstill in the development of Danish forestry, especially on the literary side, although the views of Reventlow had their effect in practical silviculture.

About 1870 a new period of development was signaled by the foundation of the Danish Heath Society in 1866 and the start of the first Danish Journal of Forestry in 1875. The Heath Society was founded mainly through the influence of E. M. Dalgas. It is chiefly due to its work and to the plantations of the State that the wooded area in Denmark has been about doubled since our last unfortunate war with Germany in 1864. 'What outward was lost must inward be gained' was the device under which this movement made its beginning.

The *Tidsskrift for Skovbrug* ('Journal of Forestry') was started by P. E. Muller, Professor of Forestry, and in the last years of the seventies there appeared in this paper his famous studies on mild and raw humus,¹ which have served as a basis for the greater part of later investigations in soil-science all over the world.

Since then Danish silviculture has developed quickly and independently.

¹ *Studien üb. d. natürl. Humusformen u. deren Einwirk. auf Vegetation u. Boden*, Berlin, 1887. French edition, Nancy, 1889.

The deeper knowledge of the nature of soil has been used in devising successful silvicultural methods. The art and science of thinnings has been developed gradually to such a point that production, at least quantitatively, cannot be much increased.

Thinnings in Denmark are begun very early, namely, at an age of 15–20 years, and are repeated at short intervals, in early life every 2–3 years, in the middle ages 4–6 years, and in old stands 6–10 years. The method of thinning is a combination of crown and low thinning. The best and biggest trees are selected and favoured vigorously at every thinning, so that their crowns develop freely on all sides. At the same time one tries to protect the soil by keeping all the smaller trees that are doing no harm to the upper class of selected trees, and which are able to live on and form suitable, broad crowns in the half-shade under the aristocrats of the forest. The number of stems in that way is reduced very quickly. At 50 years one has in beech 360 and in oak 160 stems per acre. The result is large production. For beech many districts continually yield above 110 cubic feet (Q.G.) per acre per annum. The average production of Denmark (big and small properties, crown lands, and privately owned forests) is 80 cubic feet per acre per annum. Further the dimensions of the felled stems are large for the age of the stand, and the quality is high because one has placed one's increment on a set of selected stems. The final crop will generally be under 50 per cent. of the total production.

In other branches of forestry, also, good work has been done, e. g. on heredity in forest trees by the leader of the Experimental Service, Professor Dr. A. Oppermann (Reports of the Experimental Service, 1909), and it may be mentioned finally that Danish foresters have in the last forty years worked extensively with exotic conifers, of which up till now Sitka spruce and Douglas fir have proved the most valuable.

Such then is a brief outline of the principal features of early forestry investigations in Denmark. They provide an introduction to what has now to be said about more recent work.

FOREST INVESTIGATIONS IN DENMARK DURING THE LAST FIVE YEARS.

Among the publications of the Forestry Experimental Service during the last five years the following papers are the most interesting to foreigners.

The Director of the Service, Professor Dr. A. Oppermann, has published two large monographs: one on *The Cultivation of Larch in Denmark* (1923) and another on *The Scots Pine in Middle and West Jutland* (1922).

In the first the old larch plantations in Scotland and their history are also thoroughly treated, but of course most of the work is devoted to the larch in Denmark. This species has, for some time, been almost abandoned by foresters on account of the *Dasyscypha Willkommii*,¹ after having been introduced into the country about 150 years ago with the greatest hopes.

The author comes to the conclusion that the European larch deserves a definite place in our silviculture, as it gives a valuable production, when suitable races and the right treatment are employed. Amongst the other species of larch, *Larix leptolepis* has hitherto proved the most promising.

In the second monograph the author shows that it is probable that the original race of Scots pine has never been quite extinct in Denmark, which

¹ Called *Dasyscypha calycina* in Britain.

was believed hitherto. When the area of Scots pine woods decreased, as was the case about 100–200 years ago, the explanation is to be sought in big forest fires and the abuse by the population.

Oppermann has also published papers on such other subjects as 'The Health of the Spruce and Fir in the Permanent Sample Plots of the Experimental Service', 'The Corsican Pine in Denmark', 'The Douglas Fir in Denmark', and 'The Sitka Spruce in Denmark', &c.

Professor Johs. Helms gives a very interesting report in 1922 on 'Some Plantations of Spruce in Middle Jutland'. The author has worked as a practical forester in Jutland and has there started a number of practical experiments which have led to a standardization of a method of creating in the cheapest and quickest way a young stand of spruce on heath of very poor quality. Intensive preparation of the soil by agricultural use for about three years with liming is given and then a mixture of spruce and mountain pine in the proportion 3 to 1 is planted.

In 1923 and 1925 C. H. Bornebusch published some interesting papers on 'The Flora and Soil of Danish Woodlands'. According to the flora growing on forest soils the author draws up a number of types (the *Myrtillus* type, the *Pteridium* type, &c., up to the *Circaea* type and the *Mercurialis* type) corresponding to the different qualities of the soil. For deciduous woods in Denmark he has deemed it necessary to make a distinction between *fundamental* types and *conditional* types, as altered conditions are able to change, to a certain extent, the quality of the soil as well as the flora. The degree of acidity and generation of assimilable nitrogenous compounds vary for the different types. In the opinion of the author, therefore, it is possible to arrive at rather exact conclusions relative to these matters by studying the flora.

Detailed investigations have been made also on the relation between the flora and the growth of the ash wood. Experiments have shown that when in grassy peat bog with an ash plantation the ground is covered with brushwood of beech the growth of the ash plants will be increased at the same time as a nitrophilous flora comes in. The hydrogen-ion concentration and the generation of nitric acid are thereby not much altered, but the mineral contents, on the contrary, especially the quantities of potash, are increased.

Some investigations and experiments throw light on the reaction of the remains of forest plants on the soil with regard to degree of acidity and nitrification. Evidently the herbs improve the soil for themselves (especially the broad-leaved herbs) particularly when their leaves are nitrogenous. The acidity of the soil is diminished and the content of nitrogen is increased. Hence woods should be thinned so as to permit broad-leaved herbs to grow, whereas the grass should not be encouraged as it is considered to be less favourable, or even detrimental, to the soil. Finally the author makes it clear that it is possible, by drawing up the buffer graph of dry peat and calculating the amount of dry peat per acre, to figure out how much lime is required to neutralize the acid and change the peat into mild humus.

From the contents of the last five or six volumes of the *Dansk Skovforenings Tidsskrift* ('Journal of the Danish Forest Society', started 1916), the following few papers have been picked out as the ones of greatest interest abroad.

About 1920 the *Dauerwald-sturm*¹ burst out in Germany, as it will be

¹ See Professor Troup's article on the 'Dauerwald', page 78.

known, and called to action some Danish foresters having similar ideas. In 1921 F. Muus (influenced by H. Mundt) published an essay on 'Offences against the Forest Nature by our Ordinary Methods of Silviculture', in which it was pointed out that we damage the soil by opening the forest, when we regenerate a whole compartment at a time. The author therefore considered variations of selection cutting preferable, or at least very slow regenerations whereby also the best tree forms should be obtained (education by shade). This essay has caused a long and animated discussion which is still going on, though less ardently.

More doubtlessly applicable in practical forestry is an essay by Just Holten (1921) on the European larch in Denmark, in which the author makes clear that this larch flourishes only on localities which are comparatively elevated and exposed to the free movement of the air.

In 1921 Boysen Jensen published some interesting studies on 'The Production of Material in the Forest', in which, by help of experimental investigations, he tries to prepare a kind of book-keeping account for the physiological economy of a tree with incomes (assimilation) and expenses (respiration, fall of leaves and branches, &c.). The balance throws a new light on the thinning problem. He further proves that the assimilation of a plant is almost as great at 50 per cent. of the full summer daylight as at 100 per cent., which to him explains the necessity of creating a great depth of the crowns (by heavy thinnings, perhaps selection fellings), so that as many leaves as possible are exposed to reduced light.

In 1922 Fr. Weis reported on some successful experiments made in Jutland by Alex. Foss with the purpose of producing oak wood on heath land by means of preparation and artificial manuring of the ground.

The German silvicultural methods have been studied closely in the field by Carl Mar: Møller, who has reported thoroughly on this topic in 1923.

In 1923 Carsten Olsen, by some detailed studies on the hydrogen-ion concentration of forest soils and its influence on the herbaceous vegetation, showed how a simple observation of the latter is enough to give us a well-founded idea of hydrogen-ion concentration. Experiments seem to show that it is the pH in itself which determines what plants can thrive on the ground.

The reaction of the soil of the beech wood and its power of nitrification has been specially investigated by Fr. Weis (1924), who has examined 780 samples with the interesting result that, although pH as a rule is proportionate to the quality of the soil as forest ground up to a certain point, nevertheless the very best beech forests can often show an extremely low pH, even down to a pH of 3.5. This is probably caused by the very active nitrification which results in comparatively large quantities of free nitric acid being formed in the soil. The fact that some of the best soils are so sour, however, makes it necessary to verify to a certain extent our ideas of lime as an improver of the fertility of the ground.

With the object of arranging for the introduction of better races of beech into Denmark, two Danish foresters were sent in 1925 to Czechoslovakia in order to try to trace the exact origin of some very fine middle-aged Danish stands, which are believed to have arisen from so-called Hungarian beech-nuts. It was found that certain Carpathian beech-forests showed a form very similar to that of the Danish stands mentioned above, and the necessary arrangements

have been made with the Czechoslovakian Government to provide Denmark with the seed wanted. (Report by Quist in 1926.)

In 1926, also, O. Fabricius published a detailed monograph of the two species, the Douglas fir and the Sitka spruce, where the bulk of present information on this topic will be found. The stress is naturally put on the development of the species under Danish conditions, but the data available abroad are included.

Finally, the volume of 1926 contains a report by Bavngaard on the condition of health of the silver fir in Denmark, which suffers from attacks by *Chermes picea*.¹ It is indicated that the attacks are worst in the coast districts. On more elevated localities in the middle of the country they are rarer and not so serious. There they can easily be kept down by spraying with 5 per cent. lysol.

The publications of the Journal of the Danish Heath Society are generally of a more popular character; they are not reported here on account of the limited space, but some interesting papers by Chr. Dalgas, the technical leader of the Society, on different methods of forming and managing heath plantations should be mentioned.

In the Reports of the Royal Danish Society of Sciences, however, several papers have been published which are of interest for foresters:

Raunkiaer reports (1923) on some investigations on the hydrogen-ion concentration of the soil under fifty-year-old stands of beech, oak, and spruce planted on a waste, an old grass plain in the 'Dyrehave' near Copenhagen, whereby it has been possible to control the effect produced by the different stands on the reaction of the soil. The following figures are averages: pH of the original grass plain is 6, of oak wood 6, of beech wood 5, of spruce 4.

Further, P. E. Muller has published (1924) a weighty dissertation on the formation of the heath plains of Jutland. It is probable that they have never been covered with woodland such as hitherto has been believed.

The following works, finally, have appeared independently in book form:

L. A. Hauch: *Danmarks Trævækst, 1919-23* ('The Growth of Trees in Denmark', giving a detailed and critical report on the woodland conditions and silviculture of the country).

L. A. Hauch: *Den lukkede Skov* ('The Closed Forest', discussing the modern ideas of the treatment of the wood from a more conservative point of view, advising the use of more delicate methods than hitherto).

J. M. Dalgas: *Tilvækst- og Udbytteoversigter, 1920* ('About a hundred Danish Yield Tables', which give a good idea of the Danish thinning methods and their development).

C. V. Prytz: *Skovbrugsøkonomi, 1920* ('Instructions in Forest Economy', for Students).

J. E. V. Boas: *Dansk Forstzoologi, 1924* ('Danish Forest Zoology').

A. Howard Grøn: *Skov og Folk, 1925* ('Forest and Population', a popular representation of forestry to the orientation of the people, published on the initiative of the Danish Forest Society).

Johs. Helms: *Skovdyrkningslære, 1925* ('Instruction in Silviculture for Students').

¹ Known in this country as *Dreyfusia nüsslini* (Börner).

A. S. Sabroe: *Forestry in Denmark*, a guide to foreigners, 1926 (in English. Published by the Danish Forest Society).

All the publications of the Forestry Experimental Service are accompanied by a summary in English, French, or German, and every year a summary of the contents of *Dansk Skovforenings Tidsskrift* is given in one of the same three languages, so that Danish forest literature is not at all inaccessible to foreigners. Probably the present report might induce foresters in the British Empire to enter into collaboration with their Danish colleagues, an action which would be highly appreciated in our country.

FOREST RESEARCH WORK IN FINLAND

BY LAURI ILVESSALO, Ph.D.

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FOREST research work in Finland could not start, strictly speaking, until higher education in forestry had been transferred from the Evo Forestry Institute to the University of Helsinki. Several notable investigations, however, came from the pen of Dr. A. G. Blomqvist (1836-1904), the Director of the Institute of Evo for many years, as for instance the two studies dealing with the growth of the two principal forest trees of Finland, and the work *Forest Economics and Points in Forest Policy* (1893), and the following monographs: *The Tree Species of Finland described from the Point of View of Forestry*: I. *The Pine* (1881), and II. *The Spruce* (1883), but they were only isolated cases. Determined and systematic research work could not be started and developed in such a remote and hidden-away place as Evo, which was so far from the centres of culture. The opportunities in Helsinki, the capital of the country, were very different. Here it was possible to place education in forestry on a solid scientific basis, and, apart from instruction for forest service examinations, to arrange facilities for studies for higher academic degrees in forestry, because the research instruments were far better, and scientific research in so many other branches of science was a direct incentive to forestry research also. Indirectly, the transfer of higher education in forestry from Evo to Helsinki also brought about the establishment of the Society of Forestry in Finland (1909), which was to serve as a connecting link between people interested in Finnish forest research work. Still wider prospects of power and growth were opened up for Finnish forestry research by the establishment in 1917 of a special experimental institute, the Forest Research Institute, subsidized by the State and consisting of three departments: Department of Silviculture, Department of Forest Mensuration and Valuation, and Department of Forest Soils, each of which is represented by a professor.

In these two institutions Finnish forestry research is concentrated for the present: independent, private research work in the Society of Forestry in Finland; and investigations comprising wide areas or requiring experiments of long duration and, therefore, exceeding the means of private investigators, in the Forest Research Institute. By each of them a series of its own proceedings is issued: *Acta Forestalia Fennica* (abridged below to *A. F. F.*) by the Society of Forestry in Finland, *Communicationes ex Instituto Quaestionum Forestalium Finlandiae editae* (abridged to *C. I. F. F.*); of the former series 30 volumes containing over 100 investigations have been published in 1913-26, of the latter, in 1919-26, 10 volumes containing 33 investigations. At the end of 1926 the Society of Forestry in Finland started another series of proceedings entitled *Silva Fennica*, in which minor studies are to be published.

In the research work so far carried out in Finland, an effort has been made to direct attention mainly to such questions as are of actual practical importance to the forestry of Finland. The great bulk of this research work has been

¹ The same author has recently published: 'Forest Research Work in Finland'; 'The Origins and Development of Forest Research Work'; and a 'Review of the Investigations carried out up to date'. Reprinted from *Acta Forestalia Fennica*, 31, 1926.

mainly of a comparative kind, whilst experimental researches, which in forestry, as a rule, require plenty of time—years, often scores of years—and, therefore, require ample funds, were not instituted to any extent worth mentioning until the Forest Research Institute embarked on its activities.

The forestry researches carried out in Finland may be combined into three groups: (1) *biological* and *silvicultural* investigations, (2) those dealing with *forest mensuration* (and forest valuation) and *forest policy*, and (3) those concerned with *forest utilization*.

Among the works of the first group 'Forest Types' (*A. F. F.* 1, 1909, in German) by A. K. Cajander, which has turned out to be of immense scientific as well as practical importance to Finnish forestry, should be mentioned in the first place. The same theme was further developed by the author in his paper 'Forest Types', II (*A. F. F.* 20, 1921, in German), and, especially, in his publication 'The Theory of Forest Types' (*A. F. F.* 29, 1926, in English), in which the theory of the forest types is shown to embrace still wider scope and opening important vistas not only for forestry, but also for the history of settlement and civilization as well as for settlement policy and international silviculture. The forest type researches are supplemented in many respects by the investigations of some other research workers, among which may be mentioned Raf. Björkenheim's 'Contributions to the Knowledge of Some Forest Types occurring in the Spruce Forests of the German Central Mountains' (*A. F. F.* 6, 1919, in German), O. J. Lakari's 'Investigations of the Forest Types of North Finland' (*A. F. F.* 14, 1920, in Finnish, German summary), Alvar Palmgren's 'Contributions to the Knowledge of the Characters of the Flora of the Coniferous Forest' (*A. F. F.* 22, 1922, in German), Yrjö Ilvessalo's 'Vegetation Statistical Investigations of the Forest Types' (*A. F. F.* 20, 1922, in German), V. Kujala's 'Investigations of Forest Vegetation in Southern and Central Finland' (*C. I. F. F.* 10, 1925, in German), and K. Linkola's 'Investigations of the Forest Types occurring in the Swiss Alps' (*Veröffentl. des Geobotan. Instit. Rübel in Zürich*, 1, 1924, in German). The correlation existing between forest types and the properties of the soil has been studied by J. Valmari (*A. F. F.* 20, 1921, in German) and V. T. Aaltonen (*C. I. F. F.* 9 and 10, 1925 and 1926, in German).

A pioneer achievement in its domain is also A. K. Cajander's great work *Principles of Silviculture*: I. *The Main Features of Plant Biology and Plant Geography* (1916, in Finnish), and II. *The Main Features of Finnish Dendrology* (1917, in Finnish). This work is meant to be a manual, but at the same time it contains a large number of the author's observations not published elsewhere.

An object of much research work has been the biology of the native forest trees, especially the natural reproduction of the various species of trees, so important particularly from the point of view of silviculture. V. T. Aaltonen has published an investigation based on careful and exact observation: 'On the Natural Reproduction of the Heath Forests in Finnish Lapland' (*C. I. F. F.* 1, 1919, in Finnish, German summary). The recurrence of the reproduction years of the pine has been investigated by August Renvall ('The Periodic Phenomena presented by the Reproduction of the Pine at the Polar Forest Limit', *A. F. F.* 1, 1912, in German), O. J. Lakari ('Investigations on the Seed Years and Age-classes of the Heath Pine Forests in North Finland', *A. F. F.* 5,

1915, in German), and Lauri Ilvessalo ('Investigations on the Reproduction Years of Pine Forests in South and Central Finland', *A. F. F.* 6, 1917, in Finnish, German summary); the recurrence of the reproduction years of the spruce by O. J. Lakari ('Investigations of the Reproduction Years of Spruce Forests in South and Central Finland', *C. I. F. F.* 4, 1921, in Finnish, German summary). On the vegetative reproduction of the native species of trees Olli Heikinheimo published quite a number of interesting results of investigations. The natural history, occurrence, and reproduction of the black alder in Finland has been studied by Viljo Kujala ('The Black Alder (*Alnus glutinosa* (L.) Gaertn.) in Finland', *C. I. F. F.* 7, 1924, in Finnish, German summary). To the root competition and its bearings on the development of stands and on silviculture V. T. Aaltonen has paid attention in several of his publications.

The theoretical fundamentals of the cultivation of foreign species of trees have been set forth by A. K. Cajander in Part II of the *Principles of Silviculture*, mentioned above. A. F. Tigerstedt reports in his publication *Arboretum Mustila* on the results achieved by the large-scale experiments with the cultivation of foreign species of trees carried out in *Mustila*, of Elimäki. The general conditions for the cultivation of foreign species of trees, especially the meteorological factors and the origin of the seeds, have been elucidated, apart from Cajander, also by Lauri Ilvessalo ('On the Possibilities of Cultivation of Foreign Species of Trees, with Special Regard to Finland', *A. F. F.* 17, 1920, in Finnish, German summary).

On cultivation by burning, practised in Finland from time immemorial, Olli Heikinheimo has published an extensive study: 'The Influence of Cultivation by Burning on the Forests of Finland' (*A. F. F.* 4, 1915, in Finnish, German summary). The application of the silvicultural methods, especially of the various reproduction cuttings to the forests of Finland, has been investigated by A. K. Cajander, V. T. Aaltonen, Olli Heikinheimo, G. H. J. Enroth, &c.

As to damage and injuries suffered by forests, investigations have been published by A. J. Bonsdorff on damages caused by wind (*A. F. F.* 8, 1918), Olli Heikinheimo on snow breakage (*C. I. F. F.* 3, 1920), Eino Saari on forest fires (*A. F. F.* 26, 1923), and Uuno Saalas on damage wrought by bark-beetles (*A. F. F.* 10, 1919). The harmful effects produced by the use of forest for grazing purposes have been elucidated especially by S. E. Multamäki. August Renvall has published a comprehensive inquiry: 'On the Question of Protection Forests, I-VI' (*A. F. F.* 11, 1919, in Finnish, German summary). The same subject has been dealt with by Olli Heikinheimo in his study: 'On the Forests at the Forest Limit in Finland and their Future Treatment' (*C. I. F. F.* 4, 1921, in Finnish, German summary).

Swamp investigations bulk fairly large in Finnish forest research, which is due to the fact that one-third of the entire land area of Finland is covered by swamps. A pioneer work in this domain is A. K. Cajander's *Studies of the Swamps of Finland*, in which the different modes of the origin of the swamps in Finland and the Finnish swamp types are described. On the basis laid by Cajander the investigation of the origin and development of swamps has been carried on by his pupils A. L. Backman ('Investigations of Swamps in Central Ostrobothnia', *A. F. F.* 12, 1920, in Swedish, German summary), and Väinö Auer, of whose numerous investigations only the following one need be men-

tioned: 'On the Origin of Cords on Swamps' (*A. F. F.* 12, 1920, in German). The formation of the tree-stump strata found in swamps has been investigated by O. J. Lukkala ('Investigation of the Stump Strata of Swamps', *A. F. F.* 16, 1920, in Finnish, German summary). Of considerable scientific and practical importance is Antti Tanttu's publication, 'Investigations of the Afforestation of Drained Swamps' (*A. F. F.* 5, 1915, in Finnish, German summary). S. E. Multamäki has dealt with afforestation of swamps and the growth of forest on drained swamps, and P. Kokkonen with the circumstances affecting the condition of drainage canals.

Among the investigations concerning forest mensuration (with forest valuation) and forest policy the first place is occupied by Werner Cajanus's publication: 'On the Development of Even-Aged Forest Stands' (*A. F. F.* 3, 1914, in German), in which the mathematico-statistical methods, which since then have been generally adopted, especially in Finland, in investigations concerning forest mensuration and valuation, and which have furnished them with a firmer basis than before, have been applied to forest mensuration and valuation. After A. K. Cajander had preliminarily demonstrated in his *Forest Types* that the system of forest types is more naturally fitted to serve as a basis for the classification of forest lands than the more or less artificial methods that have hitherto been in general use, Yrjö Ilvessalo definitely proved in his publication 'Investigations of the Importance of the Forest Types with Regard to Forest Mensuration' (*A. F. F.* 15, 1920, in Finnish, German summary), by means of research materials derived from sample plots in 467 stands in various parts of the southern half of the country, the suitability of the system of forest types for the aforesaid purpose. On the same research materials are based Ilvessalo's 'Growth and Yield Tables for the Pine, Spruce, and Birch Forests of the Southern Half of Finland' (*A. F. F.* 15, 1920, in Finnish, German summary). In his publication 'Investigations of the Internal Structure and Development of Even-Aged Nature-Normal Pine Stands, based on Materials from the Southern Half of Finland' (*A. F. F.* 30, 1925, in German), Erik Lönnroth describes the development of virgin pine stands on the most common forest types in South Finland. The dependence of the growth of trees on meteorological conditions is described by Erkki Laitakari in his publication 'Investigations of the Influence of the Meteorological Factors on the Height and Diameter Growth of the Pine' (*A. F. F.* 17, 1920, in Finnish with a German summary).

Among the investigations dealing with the movement of timber prices may be mentioned Eino Saari's 'The Stumpage Price and the Sale of Saw Timber in the Finnish State Forests in 1913-22' (*A. F. F.* 26, 1923, in Finnish, German summary). Finnish forestry as a source of employment is investigated by A. Benj. Helander in his study 'On Employment afforded by Forestry' (*A. F. F.* 26, 1923, in Finnish with a Germany summary).

In recent years a number of forestry statistical investigations have been carried out. The most notable both for its dimensions and its importance is the general survey of the forests of the country which was carried out under the direction of Yrjö Ilvessalo in 1922 and 1923, and on the basis of which Finland is better informed about her forest resources than any other country. The most salient data obtained by this investigation have been published in two preliminary communications, and the final report will soon be finished.

On the condition of the forests in the parishes of Sahalahti and Kuhmalahti Werner Cajanus had collected research materials as early as 1912, the further elaboration of which devolved, after the death of Cajanus, on Yrjö Ilvessalo, who published the results under the title 'Investigations on the Condition of the Private Forests in the Central Parts of the Province of Häme' (*A. F. F.* 9, 1919, in Finnish, German summary). In all these investigations use has been made of the line-survey method, the suitability of which for these purposes had been established, and the possible sources of error and their elimination analysed and discussed by Werner Cajanus, J. W. Lindeberg, Yrjö Ilvessalo, and M. Lappi-Seppälä. Eino Saari has published the study 'The Domestic Consumption of Wood in the Country in the Province Turku-Pori' (*C. I. F. F.* 5, 1922, in Finnish, German summary).

The question of the distribution of fertile land, so important from the point of view of settlement history and settlement policy, has been studied, along the broad lines laid down by A. K. Cajander, by O. J. Lukkala ('Distribution of the Fertile Soil Area especially in Savo and Karjala (Caretia)', *A. F. F.* 9, 1919, in Finnish, German summary), and K. Linkola ('On the Distribution of Agricultural Settlements among the Soils of the Different Forest Types in Finland' (*A. F. F.* 22, 1922, in German). The policy observed by the State in granting land for settlement and other such purposes has been treated from the point of view of forest policy by Mauno Pekkala.

The export of Finnish forest products has been dealt with in the investigations of Heikki Renvall, T. W. Paavonen, and J. T. Hanho, the export duties on forest products particularly in those of A. Benj. Helander.

In addition to private individuals certain State committees have undertaken investigations concerning forest policy.

Forest utilization has so far been investigated in Finland to a very restricted extent chiefly for the reason that the comparatively expensive instruments (laboratories and machinery) required by these kinds of investigations have been wanting. Quite recently I. Lassila published an interesting critical review: 'The Mechanico-Technical Properties of Wood, Their Study and Objects' (*A. F. F.* 31, 1926, in Finnish, English summary). A number of investigations have been published on cellulose chemistry and dry distillation.

DAUERWALD

BY PROFESSOR R. S. TROUP, F.R.S.

FEW terms in European forestry have enjoyed more notoriety in recent years than that of *Dauerwald*. This term may be translated concisely as 'continuous forest', that is, forest so treated that the cover is continuously maintained, and the soil is never exposed. The term was first brought into prominence in an article published in 1920 and 1921 by the late Dr. Alfred Möller under the title 'Kiefern-Dauerwaldwirtschaft'.¹ In this paper Möller describes the management, over a period of twenty-nine years, of a Scots pine forest in the estate of Bärenthoren in the German State of Anhalt, belonging to Kammerherr Friedrich von Kalitsch.

The term *Dauerwald* is applied by Möller not to any one method of treatment, but to any system not involving clear-cutting and the exposure of the soil: he thus divides the various methods of treatment into two groups (1) *Dauerwald* methods, in which the soil is never exposed, and (2) clear-cutting methods, in which the soil is exposed for a time before being covered with a new crop.

Möller's paper was followed by numerous criticisms, both favourable and otherwise. The interest stimulated by the subject induced the writer to visit Bärenthoren in 1923 in order to study the method of treatment on the spot, and a description of the treatment may afford some idea of what is aimed at.

The forests of Bärenthoren, rather more than 1,600 acres in extent, on more or less level country at an elevation of 420 feet, are composed mainly of Scots pine originally raised artificially on old cultivated land. The climate is dry, with a normal rainfall of about 22 inches. The soil is diluvial sand, usually fine-grained, with pebbles and small boulders of flint and granite. The pine trees are of a race with short branches and narrow conical crowns, and appear to be more shade-bearing than is usual with this species. Seed-years are of frequent occurrence, and regeneration springs up in great abundance. It is important to note that regeneration is equally abundant in other pine forests in the neighbourhood not treated under *Dauerwald* principles, thus disproving Möller's contention that the success of natural regeneration at Bärenthoren is due to the special treatment there.

According to records available since the early part of last century, the state of the crops was at one time extremely poor, owing to the removal of litter as well as to overcutting and general neglect. In 1883 Herr von Kalitsch stopped these abuses and introduced the treatment with which he has persevered to the present day. It has been claimed that the soil quality has thereby been raised from 4th to 2nd, while the stands have improved greatly in vigour. Möller produces figures showing that whereas the annual cut in 1872 was 21 cubic feet per acre, it rose during the period 1884 to 1913 to an annual average of 47 cubic feet per acre; also that the volume of the growing stock increased during the same period by 43 cubic feet per acre, apart from what was removed in the annual cut. The accuracy of these figures has been disputed by several writers.

¹ *Zeitschrift für Forst- u. Jagdw.*, Jan. 1920, 4-41, and Feb. 1921, 70-85. Reprinted under title *Dauerwaldwirtschaft*, 1921. See also *Dauerwaldgedanke*, by the same author (Berlin: Julius Springer, 1922).

The general lines of the *Dauerwald* treatment at Bärenthoren are as follows:

- (1) At least 50 cubic metres of *Derbholz* (i.e. timber 7 cm. in diameter and over) are constantly maintained on every hectare;
- (2) the maximum increment possible is aimed at with the minimum capital;
- (3) the fellings consist of thinnings repeated every two or three years in the same place; until recently they were carried out annually over the whole forest;
- (4) there is no rotation and no diameter limit for felling; no tree, however large, is removed if it is still growing vigorously, while trees of all sizes are removed if they have lost their vigour or are diseased, malformed, or otherwise undesirable;
- (5) all tops and branchwood from the thinnings are left on the ground to decay; they form a deep moist layer of humus with a covering of *Hypnum* moss, which is favourable to natural regeneration;
- (6) natural regeneration is relied on, and springs up freely wherever light is admitted, the trees producing seed in abundance at an age of 50 years or less;
- (7) the annual yield is not fixed in any way; a careful record is kept of the out-turn of each compartment, and every 10 years a fresh enumeration of each compartment is carried out; the average out-turn for some years prior to 1923 was 43 cubic feet per acre per annum.

The essence of the treatment may thus be said to be constant tending of the soil and growing stock by means of thinnings repeated at frequent intervals. It will be of interest, therefore, to consider how these thinnings are carried out, and what types of stand are produced.

Originally raised artificially on open land, the stands in their earlier stages were even-aged plantations, and were tended like any other plantations, being kept sufficiently dense to promote clean stems. Regular thinnings now begin at an age of 20 years. At about 40 years the opening of the canopy begins, and at each subsequent thinning it is still further opened out, with the result that natural regeneration makes its appearance in quantity. The overwood might now be safely removed in favour of the young crop, but this would be contrary to the principle of maintaining not less than 50 cubic metres of *Derbholz* on every hectare, and of retaining all vigorous stems for the production of increment. Hence no attempt is made to uncover the young crop, which makes its way up as best it can; in this respect, the somewhat shade-bearing character of the pine in this locality is in its favour.

At this stage the usual appearance of the crop is that of two-storied high forest. Where the removal of the overwood has been carried out more gradually, a selection type of forest results. Again, a stage may be reached in which there is no large timber left in the stand, the requisite amount of *Derbholz* being provided by the young crops. This form, which resembles an even-aged pole wood, is not desired, since the aim is to retain as far as possible a certain amount of old wood and produce an uneven-aged crop. In places where the stand has been kept dense longer than usual and then opened out, flourishing even-aged regeneration after the manner of the uniform system results, indicating that this system could be applied with perfect success.

Such is the treatment followed at Bärenthoren, which exemplifies an idea that is by no means new. The *Dauerwald* idea, in fact, has been applied more

or less experimentally in various localities, including Eberswalde, Hohenlühbichow, Freiburg, Barr in Lower Alsace, and elsewhere. The ideas embodied in the present-day conception of *Dauerwald* in regard to the continued maintenance of soil-fertility, together with maximum sustained production, do not differ radically from those put forward by the Frenchman Gurnaud in 1879, and subsequently elaborated by M. Biolley in Switzerland and brought to fruition by him in the forest of Couvet and other forests of the Val de Travers.

The main principles of the *Dauerwald* idea as illustrated at Bärenthoren and elsewhere may be summarized as follows:

(1) Continued maintenance of soil fertility, in order to secure 'a continuous harmonious co-operation of all factors of growth', thus stimulating the maximum production; hence the permanent maintenance of the forest cover, and avoidance of clear-cutting;

(2) production is the key-note of the idea; everything that is vigorously producing good timber is retained, while everything that is not doing so is removed;

(3) abandonment of the idea of the normal forest, normal distribution of age-classes, and rotation; complete elasticity with the object of securing maximum production;

(4) the establishment of the requisite amount of regeneration is only a secondary consideration; natural regeneration is intended to be stimulated by the favourable soil conditions produced, and to appear without difficulty, but if necessary artificial regeneration may be resorted to;

(5) elaborate calculations for fixing the annual yield are abandoned in favour of the determination of the increment by periodical remeasurements.

In criticizing *Dauerwaldwirtschaft*, it should be remembered that it is not a system in itself, but rather the expression of an idea. Towards the end of the eighteenth and during the early part of the nineteenth century, Germany was obsessed with the idea of clear-cutting with artificial regeneration on a large scale, and Switzerland, under German influence, also went in extensively for this system. Species were introduced into localities where they were never intended by Nature to grow. Spruce in particular was raised in artificial crops, often outside its natural habitat, with the object of producing the highest financial returns, without sufficient regard to the requirements of silviculture and the reaction between the forest and the soil. In many cases soil deterioration followed, growth suffered, and unhealthy crops resulted. Consequently the clear-cutting system fell into disrepute, and the *Dauerwald* idea, which represents only one of the many protests made for some time past against rigid and artificial methods of raising forest crops, took shape in the effort to favour a closer adherence to natural laws.

Most of the leading principles of *Dauerwaldwirtschaft*—soil improvement, avoidance of clear-cuttings, tending of individual stems, retention of vigorous stems for the production of increment, &c.—are neither new nor peculiar to it. Its general aims are no doubt commendable, and the results achieved at Bärenthoren are highly satisfactory, though there is little doubt that equally good results could be attained by adopting a recognized shelterwood system, in which attention is given to age-class distribution and normality. It should

be remembered that the owner of Bärenthoren is himself a trained and skilful forester; the area he manages is comparatively small, and he is able to give the closest personal attention to the tending of his woods. Add to this the fact that natural regeneration springs up in abundance wherever light is admitted, and we have ideal conditions for practising a method of treatment which is able to ignore some of the fundamental maxims of forest management without serious consequences. Under less favourable conditions, and over large areas, management on these lines would run a grave risk of breaking down. Apart from any objection in matters of principle, the Bärenthoren treatment is not without its defects in actual practice. The intensive and frequently repeated thinnings take up much of the time of the staff, and increase the cost of felling and extraction—drawbacks which Möller himself recognized.

Where conditions for regeneration are less favourable than at Bärenthoren, *Dauerwald* treatment is by no means an unqualified success. At Eberswalde a form of selection forest is aimed at. Here the special features of the treatment are gap fellings of a moderate kind with artificial regeneration of Scots pine, but the difficulty of tending the small groups of pine has frequently resulted in their failure through suppression and other causes.

The *Dauerwald* idea may be regarded as a stage in the swing of the pendulum. Strict regulation, often involving clear-cutting, is necessary in order to bring virgin or depleted or newly created forests into an organized state; but if regulation and artificial measures militate against natural laws to the extent of producing adverse results there is every reason for seeking more natural methods of treatment. Some supporters of the *Dauerwald* idea, however, have gone so far as to maintain that the ideal of the normal forest, with definite rotation and relations between age-classes, is not essential in forest management, but that the test is the actual production that can be obtained continually; that the ideal of the normal forest was created at a time when European forest management was occupied in building up organized forests and providing sustained yields, but that new methods and ideals are now possible. Hence the attempt to swing the pendulum back in the direction of irregularity. Under certain favourable conditions—small areas, easy regeneration, intensive supervision—this may be feasible, otherwise there is grave risk of a reversion to chaos. Most foresters have therefore come to the conclusion that although it may possess certain merits, the *Dauerwald* idea cannot be accepted for general application if dissociated from the recognized principles of forest management, which need neither militate against natural laws nor interfere with production.

SOME FACTORS INFLUENCING THE INCREMENT OF FORESTS

An account of certain physiological work which has a bearing on the increment of plants in general, and of trees in particular

BY R. N. ALDRICH-BLAKE

1. THE PHYSIOLOGICAL CRITERION OF INCREMENT.

THE forester is rightly interested in the volume and price increment of different species of trees under similar site conditions, and of one species in different localities, and under different methods of treatment. For the physiologist, however, neither price nor volume increment yields a true measure of the productive efficiency of a given species, environment, or silvicultural system. He must employ a criterion which expresses the quantity of raw materials assimilated; a criterion unaffected by the relative looseness or compactness with which the tree welds these materials into its several organs and tissues. Hence he must measure productive efficiency by absolute volume or dry weight increment. For these are the sole criteria by which he can compare the efficiency of different species, grown in similar localities; and further, since the specific gravity of the timber of one species may vary according to the locality or silvicultural system, these criteria are the most accurate for comparing the productive efficiency of a locality or silvicultural system.

Burger (1) has recently insisted on the above standpoint. He has estimated the absolute volume of organic matter in 100-year-old Quality 3 stands of spruce, beech, and silver fir; and has found that these three species differ little in productive efficiency, when judged on this criterion. Beech produces considerably less timber than the other two species, but the specific gravity of the timber is higher. Hence one may deduce that these three species are about equally efficient in using the supply of solar energy which reaches them. On long rotations light-demanding species are less productive than shade bearers, for at an early age they cease to use all the incident light.

2. THE IMPORTANCE OF THE RATE OF ASSIMILATION OF RAW MATERIALS.

Blackman (2) has compared the dry weight increment of an annual plant with the increase of a money loan accumulating at compound interest. Dividends are added to such a loan at definite intervals of time, quarterly, half yearly, or yearly; at all events discontinuously. The more frequent the addition of interest, the more rapidly does that loan increase, and the greater becomes the importance of the rate of interest. The dry weight of the annual plant represents so much capital, and the dry weight increment in a given short period ¹ the interest earned in that period. Now, in the annual plant, at least up till the time of flowering, and in all plants during extreme youth, the increment is immediately incorporated into tissues which are more or less directly connected with the production of further increment: in the terms of the simile, there is

¹ Theoretically an infinitely short period, since the dry weight is always being increased by addition of assimilated materials. In this paper we may conveniently employ the phrase 'momentary rate of dry weight increment' to denote the rate of dry weight increase in a period so short that the compound interest effect is not appreciably felt.

an almost continuous addition of interest to earning capital. Hence, during youth at least, the momentary rate of dry weight increment is of even greater importance to a plant than is the rate of interest to a money loan. The compound interest effect is felt in all plants throughout life, but to a lesser degree as they increase in age. It is reduced by a resting period, by flowering and fruiting, and by mere increase in size.

During winter deciduous plants cannot carry out carbon assimilation, and evergreens can do so only to a limited extent. Yet the winter reduces the incremental efficiency in other ways: for preparations have to be made to face the winter and ensuing spring. Assimilates are used in the formation of winter buds, and are thus excluded from further activities until those buds unfold. It is evident, also, that the annual shoot of deciduous trees must be formed largely at the expense of assimilates stored from the previous year; for this growth takes place before the young leaves have time to carry out any extensive assimilation. Further, there is good evidence that the economy of the evergreen is similar in this respect. Hesselman (3) and Romell (4) in Sweden, Cieslar (5) in Austria, and Burger (6) in Switzerland, have all shown that the length of the annual shoots of evergreen conifers is controlled by the weather of the previous summer: while the weather of the current year influences only the time at which this growth takes place, and the width of the annual ring. All trees of temperate regions thus appear to carry out part of their annual growth at the expense of assimilates stored from the previous year. Reverting to the simile, we see that winter is a period during which the capital earns little or no interest; and that it necessitates a discontinuous addition of interest to earning capital.

All plants must sacrifice assimilates for the formation of flowers and fruits, and thus secure the perpetuation of the species. Yet, judging from Hartig's (7) observations on starch storage in beech, it appears that this tree is unnecessarily wasteful in carrying out seed production. He found that the wood parenchyma of the outer twenty annual rings of these trees was densely packed with starch during winter, and that this starch was dissolved from only the two outer rings in ordinary summers, the remainder being stored untouched against the coming of a mast year. All this potential capital earned no interest for several years.

The incremental efficiency of a tree is, however, of necessity low, compared to that of more humble plants. The tree pays the penalty for its large size. A high proportion of the assimilates is expended in the formation of trunk, branches, and main roots: all essential capital, for they connect the actively earning members, the leaves and absorbing roots; present them to their respective environments; and provide a skeleton from which further expansion takes place. Even heart wood may apparently have some value in non-resinous trees, by serving as a water reservoir in winter, as recently shown by Craib (8). But the proportion of this more or less inactive capital increases with the age of the tree, and the compound interest effect must therefore be felt to a diminishing degree.

Agriculturists and foresters should study the factors governing the momentary dry weight increment of their plants; for the importance of this rate is more or less enhanced by the compound interest effect. They should be in possession of the existent knowledge of the influence exercised by various factors on the rates of the important metabolic processes. For the forester such knowledge should prove most valuable in connexion with nursery practice; for the

younger the tree, the higher the proportion of assimilated material relegated to actively earning tissues.

In this paper an effort will be made to present some of the results of physiological investigations which have a bearing on the dry weight increment of plants. As far as possible, work on trees will be selected. Lack of space unfortunately forbids any lengthy description or criticism of the methods whereby these results have been obtained.

3. WATER AND SALT REQUIREMENT OF TREES.

The term water requirement has been used by Briggs and Shantz (9) to denote the ratio of the weight of water transpired by a plant to the weight of dry matter produced above ground. This ratio naturally varies with climatic and soil conditions, so that accurate universal application cannot be claimed for any set of figures. Pearson (10) determined the water requirement of two- to seven-year-old plants of Engelmann spruce, Douglas fir, yellow and bristlecone pines, growing them for two years in pots filled with clay loam, and adequately watered. He did not measure the transpiration during winter, but appears to have included the root increment in his calculations. For the trees investigated in this manner he found that the water requirement varied between 360 and 440. Bates (11) also determined the water requirement of these species, and in 1921 obtained figures of the same order of magnitude as Pearson's, though the yellow pine gave a higher figure, 570. Siberian larch appeared to be an economical water user, having a water requirement of 285.

It is obviously impossible to determine directly the water requirement of large trees: but Vater (12) has calculated this ratio for trees in mature stands, using von Höhnelt's (13) transpiration figures to give the water transpired per unit weight of leaf. Vater's calculations yield the following figures, admittedly mere approximations:

Beech 398. Spruce 361. Scots pine 166.

Hence trees appear to be rather more economical than most agricultural crops in the use of water, for Briggs and Shantz (l.c.) obtained figures varying between 275 for millet and 1,068 for alfalfa.

We thus have some idea of the amounts of water used by trees in the production of unit dry weight increment; but we do not yet possess quantitative data to show how far the increment is affected by variations in the supply of available water. Cieslar (l.c.), however, found that a serious drying out of the soil caused subnormal diameter growth in spruce in the year of the drought, and poor height growth in the succeeding year.

A high soil water content may prove quite as injurious as drought conditions and may bring about the death of young plants. Hole (14) attributed the failure of sal regeneration, in certain localities in India, to faulty soil aeration during the rains. Cannon (15) has studied the influence of various soil atmospheres on the rate of root growth, using tree roots for some of his experiments. Healthy root growth is essential for the general well-being and growth of a tree.

There appear to be no data concerning the effects of various salts on the dry weight increment of trees. Many foresters have described the results of manurial experiments; but, to the writer's knowledge, Möller's sand-culture experiments with Scots pine represent all our pure scientific knowledge of the effects of

mineral ions on tree growth; and his records contain but few quantitative data. Möller grew his pine seedlings in absence of some of the mineral ions known to be essential for plant growth. The needles of plants grown without nitrogen were pale green; those of plants deprived of sulphur and potassium were bleached in appearance. Lack of phosphorus was indicated by the purple colour assumed by the needles, long before this colour could be attributed to frost; lack of magnesium by the yellowing and dying back of the needles from their apices. These observations are valuable, in that they may assist the forester in diagnosing the reasons for poor growth of his plants, but they give no insight into the quantitative effects of the essential ions.

4. RESPIRATION.

It has been seen above that there is comparatively little pure scientific knowledge concerning the influences of soil factors on the increment of trees. Much is, however, known of the effects of subaerial factors, at least in so far as they influence the rates of the chief anabolic and catabolic processes, carbon assimilation and respiration. The dry weight increment in a given period must be largely dependent on the difference between the mean rates at which assimilation and respiration proceed during the period.

Carbon assimilation takes place only in light, and in tissues containing chlorophyll; while respiration, causing a loss in weight, occurs in all living tissues, both day and night.

A continuously increasing proportion of the dry weight of a tree is composed of lignin and cellulose, substances which are not normally respired. Cell walls and dead tissues, comparatively inactive as capital, are excused the tax of respiration to which living tissues are subjected. Hence the annual respiratory weight loss of a tree, relative to the total weight, decreases as the tree increases in age. Ramann and Bauer (17) found that two-year-old elm plants lost 31 per cent. of their dry weight during the spring months, the period of greatest respiratory activity: two-year-old beech lost 43 per cent., three-year sycamore 42 per cent., and two-year ash 44 per cent. Boysen-Jensen (18) calculated that older ash trees lose but 2 per cent. to 8 per cent. of their total weight annually by respiration.

Yet it is clear that, in a tree of any age, all living tissues respire, while the leaves and absorbing roots are the only organs engaged in procuring raw materials. Hence any account of the factors influencing the increment of trees is incomplete without some mention of the factors controlling the rate of respiration. In the present state of knowledge we can only consider respiration as a process causing a loss in weight; but we must remember that energy is liberated thereby; and that this energy may be used for the synthesis of proteins from simpler compounds, and for carrying on vital processes. The observations and calculations detailed below must be accepted with this reservation.

Lundegårdh (19) has pointed out that temperature is the most important normal external factor influencing the rate of respiration. In general, as the temperature is raised, the rate of respiration increases more rapidly than the rate of photosynthesis. Hence the temperature favourable to the most rapid increase in dry weight may be somewhat lower than that which induces the highest rate of assimilation. Stålfelt (20) found that the assimilation rate of pine needles increased up to 23° C.; but between 15° C. and 25° C. the rate of respiration increased rapidly. Hence a temperature of about 21° C. appeared the

most favourable for dry weight increment of this tree, at least under the conditions of low light intensity in which he worked. Night temperatures may exercise some influence on the net increment in a 24-hour period. Lundegårdh (21) calculated that the diurnal dry weight increment of a crop of oats might be 30 percent. higher with a mean night temperature of 10°C . than with one of 20°C .

It was mentioned above that trees respire more actively in spring than at other seasons. The following figures, obtained by Willstätter and Stoll (22), substantiate this statement, showing that the initial high respiratory activity of leaves falls off as these organs attain maturity. Ten grams of leaves (fresh weight) gave off the following number of milligrams of CO_2 per hour at 25°C . on the stated dates.

Lime.	4 May.	39.	13 May.	24.	1 June.	11.
Oak.	11 May.	49.	20 May.	35.	11 June.	13.

5. PHOTOSYNTHESIS, AND THE FACTORS WHICH INFLUENCE THE RATE OF THIS PROCESS.

There is as yet little certain knowledge of the chemistry of carbon assimilation, empirically represented by the formula:



a mere burlesque of the facts. Such knowledge as we possess has largely been gained by studying the rate of the process under various conditions. In a green leaf photosynthesis takes place in the following successive stages:

1. The CO_2 of the atmosphere diffuses through the stomata and intercellular spaces to the cellulose cell walls of the assimilating cells; and passes thence, in solution, through the cellulose walls and plasmatic membranes of these cells, to the surface of the chloroplasts.

2. At the chloroplast surface the CO_2 is reduced, and formaldehyde is probably formed as an intermediate product. Briggs (23) has adduced evidence which indicates that this stage consists of two essential parts: the first is photochemical, its rate controlled by light intensity; the second chemical, its rate governed by temperature.

3. The first formed products then polymerize, with formation of carbohydrates.

It is clear that the whole process can never proceed at a greater speed than that which is permitted by the slowest stage. Several factors may influence the rate of one stage; and one factor may influence the rate of more than one stage. In the present state of knowledge we can only consider the effects of the influential factors on the rate of the whole process, as usually measured by the rate at which CO_2 is absorbed.

The factors which influence the rate of carbon assimilation may be classified as internal and external; but the distinction is vague, inasmuch as internal factors may be partly the resultants of the previous external circumstances. Herewith is given a list of the normally influential factors:

1. Internal.
 - A. Chlorophyll content, or, probably more accurately, the relative chloroplast surface.
 - B. An internal factor, which may be styled the 'protoplasmic factor', in absence of definite knowledge of its nature.

2. External.
 - C. All factors influencing stomatal aperture.
 - D. Previous conditions affecting the degree of accumulation of carbohydrates in the leaf.
 - E. Salt supply.
 - F. Water supply.
 - G. Atmospheric carbon dioxide content.
 - H. Temperature.
 - I. Light intensity and wave length.

A. Chlorophyll Content.

Willstätter and Stoll (l.c. p. 82) found that leaves of many deciduous plants, collected in midsummer, exhibited a close correlation between chlorophyll content and capacity for assimilation. They determined the assimilation number for many species; that is to say, the quotient

$$\frac{\text{Hourly assimilation of CO}_2 \text{ in grams.}}{\text{Chlorophyll content in grams.}}$$

This quotient varied little from species to species, as is shown by the following extracts from Willstätter's assimilation numbers, obtained in June, in experiments carried out at 25° C., in a light intensity of 48,000 lux,¹ and in an atmosphere containing 5 volumes per cent. of CO₂.

Acer negundo. 7.7. Elm. 6.9. Horse Chestnut. 6.4. Sycamore. 5.2.

Thus it is clear that chlorophyll content is an important factor influencing the rate of photosynthesis. The slight variation in the assimilation numbers may be ascribed to the fact that all the leaves were not in the same developmental condition, or, more probably, to the circumstance that the amount of reactive chloroplast surface may be the important factor, rather than the chlorophyll content itself.

B. The Protoplasmic Factor.

Willstätter and Stoll (l.c. p. 90) found that the assimilation number of any species did not remain constant throughout the season; and therefore deduced that some other internal factor, besides chlorophyll content, influences the leaf's capacity for assimilation. The nature of this factor is as yet unknown: it is generally spoken of as the protoplasmic factor.

Seasonal Variation in Photosynthetic Efficiency. Owing to the interaction of two internal factors mentioned above, leaves exhibit a seasonal variation in their capacity for assimilation. In most species the maximum efficiency is attained early in the season, well before the longest days of the year, but a high efficiency is maintained throughout the summer months. Willstätter's figures for the sycamore may be given as an illustration: they represent the weight of CO₂ (milligrams) assimilated per hour per gram dry weight of leaf, under the same external conditions as those employed in the experiments cited above.

May 5.	May 14.	June 24.	July 30.	Sept. 17.	Oct. 5.	Oct. 19.
35	78	58	52	53	44	7

¹ The lux is a light intensity produced by a light of one candle-power at a distance of one metre. Forty-eight thousand lux is roughly equivalent to full sunlight at noon in midsummer in Germany.

C. Stomatal Aperture.

Space here forbids a lengthy discourse on the factors influencing stomatal aperture. Light and the water balance of the leaf appear to be the chief external controlling factors. In the majority of plants the stomata are closed during the night, open early in the morning, remain more or less open for a variable period, but generally close by sundown, frequently earlier. Stålfelt (24) found that the stomata of pine and spruce did not open widely in wet weather, but remained open for a longer period than in dry weather. In times of drought the stomata scarcely opened, and no appreciable amount of carbon assimilation took place. The tree protects itself against loss of water, but in so doing reduces its photosynthetic efficiency. We have seen above that drought years are marked by subnormal diameter growth, and by poor height growth in the succeeding year.

D. Accumulation of Carbohydrates in the Leaf.

If a leaf be subjected to conditions very favourable to photosynthesis, the initial high rate of assimilation falls off after a few hours. Pantanelli (25) ascribed this failing efficiency to fatigue; but Willstätter and Stoll (l.c., p. 81) have shown that leaves of yellow varieties, whose absolute assimilation rate is slow, by reason of the low chlorophyll content, show no such failing efficiency. Hence they conclude that the failing efficiency of the green leaf should not be ascribed to fatigue, but rather to an accumulation, in the leaf, of carbohydrates, the primary products of assimilation. Thus it may be that in nature an accumulation of carbohydrates may prevent a leaf from making full use of a day most favourable to photosynthesis.

E. Salt Supply.

It has long been known that certain mineral ions are essential for plant growth, but it is only comparatively recently that Briggs (l.c.) has shown that absence of magnesium, iron, phosphorus, and potassium induces subnormal photosynthetic activity in leaves of broad beans. Thus we now know that the effect of a lack of these ions is felt partly through a detrimental influence on the primary anabolic process of carbon assimilation. Yet this is only to be expected; for magnesium is an essential constituent of chlorophyll, and iron is necessary for the production of this pigment. Little is known of the function of potassium: but phosphorus is a component of the majority of proteins; and, if the synthesis of these bodies be prevented, it may be that carbohydrates accumulate and slow down the rate of assimilation.

F. Water Supply.

A restriction of the water supply to the leaf must clearly reduce the rate of photosynthesis, for water is an essential raw material in this process; moreover, it is necessary for the maintenance of turgidity, and for carrying on all vital processes. Thoday (26) found that flaccid sunflower leaves assimilated less actively than those fully turgid. Dastur (27) found that the water content of old leaves of *Abutilon* spp. and *Sparmannia africana* was lower than that of young leaves; and that the chloroplasts degenerated at the leaf margins, where the restriction of water supply was probably most strongly felt. There was a very close correlation between the water content and photosynthetic activity

of leaves of these plants. As above mentioned, Stålfelt (l.c. 24 and 28, p. 267) showed that drought periods resulted in the almost complete cessation of assimilation of pine and spruce, owing to the induced closure of the stomata.

Carbon Dioxide, Temperature, and Light. It is impossible to consider the individual influence of these three factors, without first making it clear that the degree of influence which any one factor can exercise is largely dependent on the intensity of the other two factors. Blackman (29), in his doctrine of limiting factors enunciated in 1905, maintained that the factor which was at any time in minimum completely limited the rate of photosynthesis. Thus, if a leaf were well illuminated in an atmosphere rich in CO_2 , but were kept at a low temperature, then no increase of the light intensity or CO_2 supply would avail to hasten the process; this could be secured only by increasing the temperature, here the limiting factor. Such a limiting effect of any one factor is what we would expect on analogy with the building of a house out of bricks and mortar. Were the rate of supply of mortar slow, then no increase of the number of bricklayers, or of the rate of delivery of bricks, would avail to hasten the building of the house.

Yet carbon assimilation is a complex, little understood process; and therefore it is perhaps not surprising that recent workers have challenged the absolute accuracy of the doctrine of limiting factors. Harder (30) and Lundegårdh (31), as a result of their experiments with a water moss and wood sorrel respectively, both maintain that no one factor sharply limits the rate of photosynthesis. The factor most in minimum always exercises the strongest controlling influence, but an increase in the other factors has some small effect.

Lundegårdh's curves, expressing the influence of varying light intensity and CO_2 concentration, at constant temperature, on the assimilation rate of leaves of wood sorrel, are reproduced in Fig. 1. We may first consider any one curve, for instance the lowest, expressing the effect of light intensity on assimilation rate, in an atmosphere containing 0.03 volume per cent. of CO_2 , the normal atmospheric content. It is a curve of the logarithmic type; that is to say, the lower the light intensity, the greater is the effect of a given increase in this factor. Comparing now the four curves for different concentrations of CO_2 , it becomes clear that the higher the CO_2 concentration, the steeper is the curve, and the greater the range of light intensity through which the curve ascends. The wood sorrel is an extreme shade bearer: hence it is perhaps more sensitive to changes in the CO_2 concentration than most plants; and it is certainly less responsive to increasing light, above a light intensity of about 15 per cent. of sunlight. To the writer's knowledge no such series of curves has been published for any species of tree; but it is very desirable that silviculturists should know whether leaves of trees respond similarly to variations of light and CO_2 concentration: for it would mean that trees could make some use of the high CO_2 concentrations near the forest floor, despite the low light intensity. This problem will be dealt with in greater detail below.

Having thus considered the interaction of the factors carbon dioxide, temperature, and light, we may now consider their individual effects on the rate of carbon assimilation.

G. Atmospheric Carbon Dioxide Content.

Some may think that an investigation of the relations between the atmospheric CO_2 content and the rate of assimilation is a fruitless study, owing to

the small variations in the quantity of this gas in the atmosphere, and the impossibility of controlling it. Yet, when combined with a careful study of the fluctuations of the quantity of CO_2 in the forest atmosphere, such results are of considerable interest.

The question whether the assimilation rate of one species is more enhanced by increasing concentration of CO_2 than that of another species cannot yet be answered with certainty, owing to insufficient comparable data; but the indications are that shade bearers are more sensitive to increasing CO_2 than light

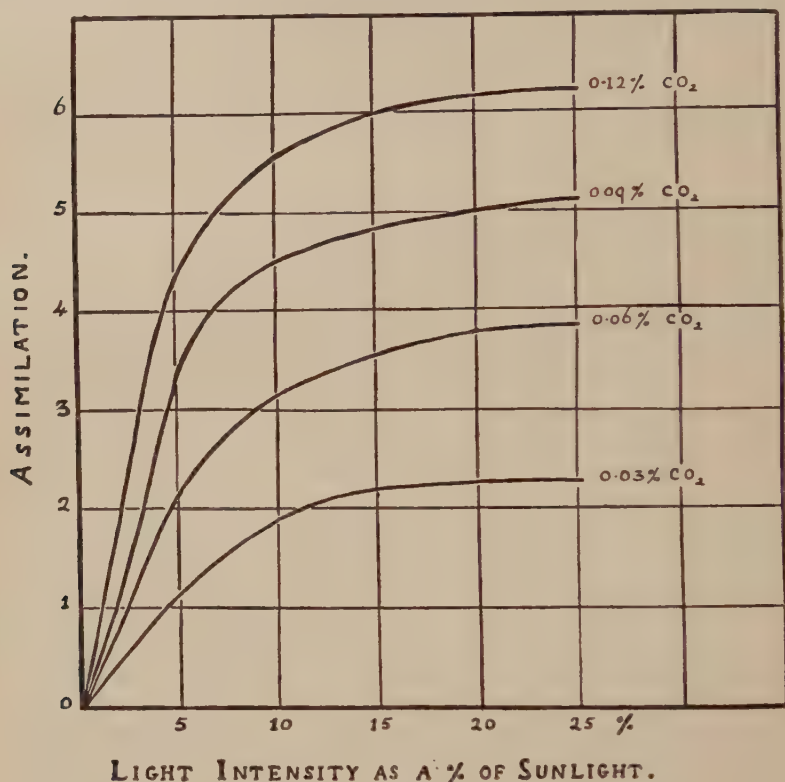


FIG. 1.

demanders. Lundegårdh's curves for wood sorrel, reproduced above, show that the assimilation increases in direct proportion to the CO_2 available, in a light intensity of 5 per cent. sunlight. Working with hornbeam leaves at 25°C ., and in a low light intensity, 4,940 lux, Kreuzler (32) found that the assimilation rate was doubled by doubling the amount of CO_2 in the atmosphere. The following are the means from three experiments, representing true assimilation (i.e. corrected for respiration) per hour per sq. decimeter of leaf surface:

Atmosphere containing	0.03	0.06	0.09	0.12	volume per cent. of CO_2
Assimilation in mg.	4.8	9.7	12.2	12.9	

Stålfelt (l.c. 24, p. 184) measured the rate of apparent (i.e. he did not correct for respiration) assimilation of one-year-old pine needles in different concentra-

tions of CO_2 . If a curve of logarithmic type be constructed from his data, the following relations between CO_2 content and assimilation can be read off. The CO_2 content of the atmosphere is expressed as milligrams per litre (0.5 mg. per litre being the normal atmospheric content), and the assimilation as mg. of CO_2 absorbed per hour per gram fresh weight of needle.

Atmosphere containing	0.5	1.0	2.0	5.0	mg. CO_2 per litre
Assimilation in mg.	1.1	1.8	2.8	3.6	

In this case, by doubling the normal atmospheric content of CO_2 the assimilation rate was increased by only 64 per cent. The light intensity was higher than in Kreusler's experiments, but the temperature is not stated, and the results are not corrected for respiration. Hence no certain comparative conclusions can be deduced, but it appears probable that the hornbeam is more sensitive than Scots pine to an increase in the CO_2 content of the atmosphere.

However, the chief lesson to be learnt from these data is the marked effect which an increase of CO_2 content exercises on the rate of carbon assimilation, even in low light intensities.

Working in Swedish woodlands, Lundegårdh (33) found that the atmospheric CO_2 content near the forest floor was the same as that outside, on windy days; while in calm weather it was frequently 30 per cent. to 40 per cent. higher. McClean (34) determined the CO_2 content of the air at breast height in a tropical rain forest near Rio de Janeiro; at 5.30 p.m. he found 0.14 per cent. of CO_2 by volume; at 6.30 a.m. 0.34 per cent., ten times the normal atmospheric content.

From Lundegårdh's results it appears that the CO_2 given off from the forest litter and soil may be of little use to the trees, if these be grown on an even-aged silvicultural system. Only at the time of regeneration operations are leaves of timber trees present in the lower strata of the forest atmosphere. During a long period of calm weather the CO_2 evolved from the soil may rise into the canopy, and there be utilized; but if the weather be windy, or alternately calm and windy, this CO_2 may be largely blown away and lost to the forest. Thus, from the physiological standpoint, it would seem that the highest rate of increment should result from the employment of uneven-aged silvicultural systems. Yet the productive efficiency of different systems can be judged only by measuring the dry weight increment per unit area of forest in similar localities. Such data we do not yet possess, and even if it be found that uneven-aged systems yield a higher increment than even-aged systems, still preference will frequently be given to the latter, owing to the greater ease of manipulation.

H. Temperature.

The most extensive work on the relation between temperature and the assimilation rate of trees was carried out by Lubimenko (35); but his methods are unfortunately rather unreliable, and he used a very high concentration of CO_2 , 8 per cent. by volume. Matthaei (36), who also used supernormal concentrations of CO_2 , showed that cherry laurel leaves began to assimilate at $-5^\circ \text{C}.$: the rate of this process increased up to a temperature of $37.5^\circ \text{C}.$, provided the period of experiment at high temperatures was very short, and the injurious effects of such high temperatures thus minimized. Willstätter and Stoll (l.c. p. 152) determined the assimilation rate of elm leaves over a short range of temperature, in 4.5 per cent. by volume of CO_2 , and in a light intensity of

48,000 lux. Their results are expressed as the number of milligrams of CO_2 absorbed per hour per gram fresh weight of leaf:

15° C.	20° C.	25° C.	30° C.
7.5	9.0	11.1	11.6

Lundegårdh (37), to whom we are indebted for the most recent work on the influence of temperature, maintains that all work in which high concentrations of CO_2 are used is misleading from the ecological point of view. He found that potato leaves assimilated more rapidly at 20° C. than at higher temperatures, in ordinary air, and in full sunlight. Under natural conditions the most favourable temperature for assimilation of plants of temperate regions probably lies well below 30° C. Stålfelt's (l.c. 20) experiments with pine and spruce point to such a conclusion, but unfortunately they were carried out in too low a light intensity to be of very great interest.

I. Light Intensity and Wave Length.

Many workers have investigated the influence of light intensity on the rate of assimilation. Before discussing any of this work we must realize that they have measured the amount of light energy falling on the leaf, not the amount actually used for assimilation. Brown and Escombe (38) calculated that only half the light falling on a sunflower leaf was used by that organ, and that most of the light absorbed was converted into heat for the vaporization of the water of transpiration; less than 1 per cent. of the incident light being employed in carbon assimilation. Working with sycamore leaves, and making his calculations from data in some respects more reliable, Puriewitsch (39) concluded that 0.6 per cent. to 2.7 per cent. of the incident solar energy was used for photosynthesis. Other workers have come to similar conclusions, and it therefore seems certain that a leaf can spare only a small proportion of its complement of light for the most important function which it subserves.

The relation between light intensity and assimilation rate is expressed by a curve of logarithmic type. Assimilation is most instructively plotted per unit of leaf surface: for this procedure reveals the characteristic differences between light-demanding and shade-bearing species, and between sun and shade leaves of a single tree. Boysen-Jensen's (40) curves, reproduced in Fig. 2, represent the apparent hourly assimilation of sun and shade leaves of elder at 20° C., and presumably in an atmosphere containing 0.03 per cent. by volume of CO_2 . The curves begin below the abscissa, for in a very low light intensity the loss by respiration is greater than the gain by assimilation. The differences between the two curves are intelligible in the light of the greater thickness of the sun leaves. Assimilation balances respiration in a lower light intensity in the thin shade leaf, for unit area of this leaf contains a smaller quantity of tissue, and in consequence suffers an absolutely lower respiration loss. Again, owing to its thin structure, the shade leaf does not respond to increase of light beyond 12 per cent. of sunlight; for in such a light intensity all the assimilating cells are presumably sufficiently illuminated to yield their maximum output. The lower tissues of the thicker sun leaf are shaded by the superincumbent tissues, and are therefore unable to yield their maximum output until the upper surface of the leaf receives about 40 per cent. of sunlight.

The elder is a moderate shade bearer, so that even its sun leaves give a light-

assimilation curve lower than that of a light-demanding species. Thus Stålfelt (l.c. 28, p. 256) found that the light-assimilation curves, for both sun and shade needles of pine and spruce, ascended up to a light intensity of full sunlight. Yet Boysen-Jensen's curves show the essential differences between the behaviour of sun and shade leaves, and they help us to understand the meaning of the light-demanding and shade-bearing habits.

The light intensity at which assimilation balances respiration is an all-important factor determining the light habitat of a plant. No plant can exist, nor can a leaf profit the plant to which it belongs, unless its mean gain by assimilation exceeds its mean loss by respiration. Lundegårdh (l.c. 19, p. 88) has collected the work of various authors on the light intensity at which assimilation just balances respiration. This work was done in ordinary air, and at a tempera-

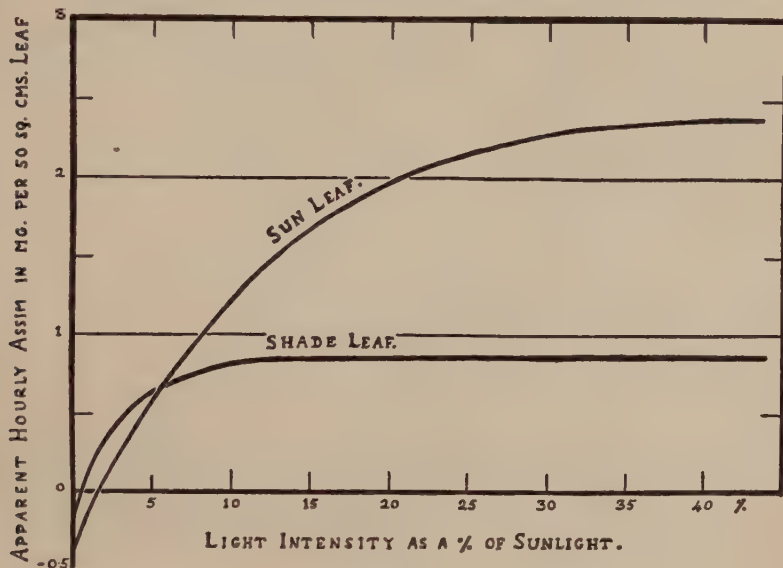


FIG. 2.

ture of 18° C. to 20° C.: the light intensities are expressed as a percentage of full sunlight.

Fontinalis, a water moss.	0.2 per cent.	Polypodium vulgare.	1.0 per cent.
Wood sorrel.	0.7 per cent.	Apple.	2.2 per cent.
Spruce, shade needle.	3.0 per cent.	Spruce, sun needle.	7.5 per cent.
Pine, shade needle.	1.8 per cent.	Pine, sun needle.	4.0 per cent.

The most productive species must use the sunlight to the greatest possible extent. It must produce a series of leaves, graded in thickness from the periphery of the crown inwards; the thick outermost leaves making good use of full sunlight, the innermost being so thin that they can show a dry weight gain in the densest shade.

So far we have only considered the assimilation of leaves in different intensities of white light; but all parts of the spectrum are not of equal photosynthetic value; and the most valuable photosynthetic rays, in the red-orange region (cf. Ursprung, 41), are strongly absorbed by chlorophyll, and conse-

quently by passage through leaves. The relatively useless green light passes through a leaf to a greater extent than the valuable red and orange rays. Willstätter and Stoll (l.c. p. 127) found that a cucumber leaf assimilated 165 mg. of CO_2 per hour at 25°C ., in 5 per cent. of CO_2 by volume, and in a light intensity of 48,000 lux. When one leaf of the same species was interposed between the experimental leaf and the source of illumination, the hourly assimilation was reduced to 16 mg.; and, when two leaves were interposed, no assimilation took place.

When light falls on a forest canopy some of it reaches the ground; through gaps in the leaf mosaic, after passage through one or more leaves, or after multiple reflection from several leaves: some of it is absorbed and used by the leaves: some is reflected back into the atmosphere. Much of the light which is reflected from a leaf probably passes into this organ as far as the cells of the spongy mesophyll. These cells abut on air spaces, and must therefore reflect a large amount of the light which reaches them. Thus light which has been reflected from a leaf is probably relatively richer in the green rays than the incident light.

From these considerations we see that the light reaching the forest floor must consist of light of the same spectral composition as the light outside, and of light relatively impoverished in the red-orange and blue-violet ends of the spectrum. Knuchel (42) has measured the quantitative spectral composition of the light reaching the forest floor under dense and thinned stands of many species of tree, and has expressed the recorded light intensity, in four regions of the spectrum, as a percentage of the light intensity in the respective regions of the spectrum outside the forest. Under both broad-leaved and coniferous stands, the light in all regions of the spectrum was naturally greatly reduced: but, whereas under broad-leaved trees the relative impoverishment in the red-orange and blue-violet regions was very marked, the light under coniferous stands possessed nearly the same relative spectral composition as the light outside. The difference between broad-leaved and coniferous stands indicates that little light is transmitted through, or reflected from conifer needles; and that such light as reaches the ground beneath a coniferous stand does so through gaps in the needle mosaic.

6. THE INCREMENTAL EFFICIENCY OF LEAVES AND NEEDLES.

Hartig (43) and Burger (l.c. 1) have attempted to find out the volume of timber produced annually by unit quantity of leaves or needles, under various conditions. There were so many variable factors in Burger's experiments that no valuable conclusions can be drawn from them, beyond the fact that the fresh weight of larch needles required to produce an annual increment of one cubic metre of timber may vary between 600 and 3,000 kilograms. Hartig's method was crude, for he used the weight of leaf-bearing twigs on oak-trees as a measure of the quantities of leaves on the trees. Yet his results are so striking that they are worthy of mention here. Leaves of trees grown on good soils produced $5\frac{1}{2}$ times as great a volume of timber as leaves of trees grown on poor soils. Leaves of 33-year-old trees produced 2.7 times as great a volume of timber as leaves of 90-year-old trees, grown on similar soils. In both cases it is probable that the reduced efficiency may be due to failing water and salt supply to the leaves. We have seen that such conditions reduce the assimilatory efficiency of leaves.

These results show that the annual incremental efficiency of leaves and needles varies within wide limits; but they do not fully express the compound interest effect, which we know to be of great moment in the increment of plants. If a given quantity of leaves produces a small volume of timber, it is probable that it also yields a small quantity of reserves for use in the shoot-growth of the following year.

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A CRITICAL NOTE ON SOME RECENT LITERATURE ON FOREST ECONOMICS¹

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INTRODUCTION.

THE great mass of German literature on forest economics which has been published since the War centres round the soil rental controversy. To British readers the soil rental theory is familiar chiefly as a matter of text-book formulae and not as a question of great practical significance in forestry; in Germany, on the contrary, it forms the line of cleavage between two schools of thought, each of which aims at predominance in forest administration, and the controversy, though frequently bitter and often lacking in statistical foundations, has given rise to certain advances in thought which are helping to free forestry from the formal economics of the text-book. The object of the present article is to give some account of the present state of the controversy and to indicate the lines along which useful progress has been achieved.

It is necessary at the outset to avoid the confusion, which is so frequent in the literature, between the question of how profit can best be estimated and the question of how far profit should be regarded as the chief aim of forestry. The first is a fundamental problem of forest economics; the second is one of the most important questions of forest policy. Forest policy, however, can never be satisfactorily formulated without a knowledge of economics, since any deviation from the most favourable economic methods involves a financial sacrifice, and a balance has always to be made between this sacrifice and the countervailing advantages which it is hoped to obtain. This is often difficult since the countervailing advantages may be of an imponderable nature, which cannot be expressed in money; but when it is proposed that sacrifices should be made the losses involved by these sacrifices can be estimated and it is then a matter for public opinion to decide whether it is worth while to make them.

SOIL RENT AND FOREST RENT.

The rental controversy, in its economic sense, has been waged round the question whether the economic object of forestry should be a high soil rental ('Bodenreinertrag') or a high forest rental ('Waldreinertrag'), but the terms are so ill chosen that some explanation of their use is necessary. Soil rent is calculated by the soil expectation value formula, commonly referred to as the Faustmann formula.² Forest rent, on the other hand, is the sustained net income from the forest, i.e. (if the capital value of the forest remains constant) the difference between gross income and gross expenditure. The fundamental difference between the two conceptions is that the first takes account of the capital invested and regards income as interest on that capital, whereas the

¹ In references to literature the following contractions have been used: *A.F.u.Ź.Z.* = *Allgemeine Forst- und Jagd-Zeitung*; *F.C.* = *Forstwissenschaftliches Centralblatt*; *F.W.S.* = *Forstliche Wochenschrift Silva*; *T.F.Ź.* = *Tharandter Forstliches Jahrbuch*; *Z.f.F.u.Ź.W.* = *Zeitschrift für Forst- und Jagdwesen*.

² $Se = \frac{Yr + Ta \times 1.0 p^{r-a} + \dots + Tq \times 1.0 p^{r-q} - c \times 1.0 p^r}{1.0 p^r - 1} - \frac{e}{0.0 p}$ where the symbols have the usual significance (as in Schlich's *Manual*, vol. iii).

second is based solely on the sustained net income from the forest and takes no account of the capital invested. The view that the soil rental theory regards only the soil as capital¹ and ignores the growing stock is a misconception which arises from bad nomenclature.

The controversy has centred chiefly round the question of the length of rotation. The rotation which gives the highest soil rental is always shorter than that which gives the highest net income, so that the highest net income involves a longer waiting. All tree cultivation involves waiting and the view of the soil rentalist is that it is economically worth while to wait up till the financial rotation but not longer. For nearly a hundred years the ambition of most of the practical foresters in Germany has been to increase the growing stock of their *Reviere* and to produce large-sized, high-quality timber. Conversion has been limited to five or six cubic metres per hectare and, as increment has generally exceeded this, the density of the forests has tended to increase and the rotation to lengthen. The growing stock has accumulated and the forests have become an object of admiration throughout Europe. Then the whole system was subjected to criticism by the followers of Pressler, the soil rental school, on the ground that the income from the forests entirely failed to justify the enormous capital value of the growing stock, and, to render the forests a financial success, much of this capital must be realized: much of the work of decades must be undone.² The conflict which ensued was characterized by much bitterness and most of it is unprofitable reading; but by the beginning of the period which the present review attempts to cover a fairly general consensus of opinion had been reached on one important point, viz. that in estimating the economic success of an undertaking the value of the capital invested in it cannot be ignored: that the net income by itself is no criterion of financial success. Wagner,³ most ardent of silviculturists, admits that nearly every one now subscribes to the soil rental theory. Reverberations of the forest rental theory still occasionally occur and it is still necessary for Trebeljahr⁴ and H. Weber⁵ to point out that nobody wants capital in his business unless it yields income. It is much better, both for the individual and the community, to realize such capital and to put the money obtained to productive use. The recent espousal of the forest rental theory in America by Chapman and Shepard will be referred to later.

THE USE OF EXPECTATION VALUE FORMULAE.

If the forest rental theory has been demolished in the conflict the soil rental theory has not survived unscathed. It has suffered, however, in rather a different way. The soil rental theory has been used for two distinct purposes, which may be described as the use in forest valuation, in the restricted sense, and the use in 'forest statics'. In forest valuation the theory has been used to estimate the value of forest land, in forest statics to compare the financial productivity of different methods of management. The two uses must be kept quite distinct.

¹ e.g. O. Mang, *F.W.S.*, xii, 1924, p. 9; Kohler, *A.F.u.Ź.Z.*, cii, 1926, p. 15.

² The position is well portrayed by C. Wagner, 'Die Verwirklichung des Reinertragprinzips in der Forstwirtschaft', *A.F.u.Ź.Z.*, ci, 1925, p. 265.

³ C. Wagner, 'Bodenreinertrag und Waldreinertrag', *A.F.u.Ź.Z.*, c, 1924, p. 120; cf. also Trebeljahr, id., p. 166. Martin, however, even in 1894, said that the controversy was dying down (*Fol.g. der Boden.*, 1st ed., vol. i).

⁴ *F.W.S.*, xii, 1924, p. 25.

⁵ *A.F.u.Ź.Z.*, c, 1924, p. 128.

The idea of using the expectation value of the soil in determining a suitable price for land is based on the surplus value theory of rent propounded by the Physiocrats and Adam Smith in the latter half of the eighteenth century.¹ This theory was an attempt to explain rent as the difference between the gross yield from cultivation and the amount paid for wages, management, interest on capital, and other expenses. As long ago as 1817 Ricardo showed that this theory did not account for rent in new countries and could have only limited application in old ones and, as will be shown later, it certainly does not apply to forest land; and yet it is still the official theory of many text-books of forest valuation.² The market price of land is determined, like the price of other commodities, by the interplay of supply and demand, and, since in Great Britain very few private persons are anxious to buy land for afforestation, the forest value of land plays practically no part in determining its price. In Germany, owing to the fact that most of the States are ready to purchase all the available forest land, prices are higher than in Great Britain and range from about £4 to £30 per acre.³

Now the value of the soil as calculated from the Faustmann formula shows vast deviations according to the rate of interest with which it is calculated. The rate of interest generally applied to calculations is 3 per cent. which, though quite out of keeping with the rate of discount to-day, was fairly applicable at the end of the last century. But on this basis a very large part of the forest land of Germany has a negative expectation value⁴ and Voss⁵ has shown that Scots pine, qualities IV and V, give a negative rental even if calculations are made with 2 per cent. On the other hand, land which can be bought in England for £10 per acre may be calculated to be worth £80, when the computations are made with 3 per cent. on its probable Douglas fir yield (quality II), and land in South Africa which can be bought for £3 per acre may, on a similar basis, have a soil expectation value of £160 when planted with *Pinus radiata*.⁶ The only way in which the forest expectation value of land can be brought into line with the market value is to calculate with 1 or 2 per cent. for Scots pine in Prussia, 3 per cent. for spruce in Saxony, 5 to 8 per cent. for Douglas fir in Britain and 9 to 11 per cent. for *Pinus radiata* in South Africa.⁷ Thus the expectation value of the land approximates to the market price only if the rate of interest is so chosen as to make it so; in other words, the Faustmann formula is useless for estimating the value.⁸ As v. Spiegel⁹ says, if land

¹ See Lemmel, 'Die Bodenreinertragslehre in sozialökonomischem Lichte', *Z.f.f.u.ſ.W.*, lvii, 1925, p. 65.

² Particularly G. Huffel, *Économie Forestière*, 1919, vol. ii, pp. 435 et seq.; in part also Lehr in Lorey's *Handbuch*, 1912, vol. iii, pp. 29, 30. Endres (*Lehrbuch der Waldwertrechnung und Forststatik*, 1919, p. 86, and *Handbuch der Forstpolitik*, 1922, p. 49) maintains that the soil expectation value gives the lower limit for market value, a view which can only be accepted with qualifications.

³ v. Spiegel, *Z.f.f.u.ſ.W.*, lvii, 1925, p. 603, proposes for estimated values of forest land 200 to 1,600 marks per hectare, according to quality.

⁴ Eberbach, *F.W.S.*, xiv, 1926, p. 101. H. Weber (*A.F.u.ſ.Z.*, cii, 1926, p. 375) fails to answer this difficulty.

⁵ *Z.f.f.u.ſ.W.*, xlviii, 1916, p. 505, and lvi, 1924, p. 616.

⁶ Based on figures given by N. L. King, Union of S. Africa, Forest Dept., *Bull.* No. 15, 1925.

⁷ Cf. Gribkowski, *F.C.*, 1924, pp. 297, 333.

⁸ Cf. Künanz, *A.F.u.ſ.Z.*, cii, 1926, p. 362. Voss (*Z.f.f.u.ſ.W.*, lvi, 1924, p. 616) says that *Se* gives a 'caricature of the facts'.

⁹ *Z.f.f.u.ſ.W.*, lvii, 1925, p. 63.

values are required for accountancy purposes it is much better to make a rough guess of the market price than to compute expectation values.

The criticisms levelled at the classical method of estimating forest land values are also applied to the use of the expectation value of growing stock. Here again, since 3 per cent. is approximately the rate of interest which many German forests yield, this rate is generally applied to the anticipated yields in order to evaluate the forest capital. V. Spiegel ¹ points out that to obtain the market value of an enterprise the income must be capitalized at, at least, 5 per cent., which will give a very much lower value than that usually adopted. On the other hand Godbersen ² shows that in forests managed on a rotation which greatly exceeds the financial rotation the actual utilization value of the standing timber may be greater than the expectation value computed on a 3 per cent. basis and consequently very much higher than the value computed on a 5 per cent. basis. Where valuations of growing stock are required for such purposes as taxation, rule-of-thumb methods are now employed which have little or no relation to the expectation value of Heyer and his school.³

By these criticisms practically the whole structure of forest valuation, as built up by Heyer and introduced to Britain by Schlich, has been demolished. To most Englishmen this will come as a confirmation of their intuitive convictions; and it will relieve them from paying lip service to formulae that always appeared to them as figments of imagination.

METHODS OF COMPUTING FINANCIAL ROTATIONS.

The Faustmann formula still has a use in the realm of so-called 'forest statics'. There are several ways of comparing the financial advantages of various methods of management or different silvicultural systems, and of these the expectation value of the soil is most commonly employed. It forms a fairly satisfactory basis for estimating the financial rotation and so long as the same rate of interest is maintained throughout any one test it does not greatly matter what rate is used. Thus Scots pine tests may be worked with 2 per cent., spruce with 3 per cent., Douglas fir with 5 per cent.; but in estimating the relative advantages of planting spruce or Douglas fir it would be necessary to calculate both with the same rate of interest. The upholders of the soil rental theory say that the silvicultural methods to be adopted should be those from which the highest soil expectation values can be calculated, and this is quite independent of any attempt to estimate the actual price of the land.

Modern economists distinguish much less clearly than their predecessors between rent and income from capital other than land, and Gribkowski ⁴ quite rightly says that it would be just as logical to estimate the expectation value of the cost of planting or annual expenses as of the land. This, indeed, may well be done for special purposes, as, for instance, when it is desired to compare the returns from cheap or expensive planting. As a matter of fact it makes very little difference which method is adopted.

Next to the soil expectation value the financial yield or rate of interest

¹ Loc. cit.

² *Theorie der forstlichen Oekonomik*, Neudamm, 1926.

³ See H. Biolley, 'Valuation of Forest Property for purposes of Taxation in Neuchâtel Canton, Switzerland', *Journ. of Forestry*, xxviii, 1925, p. 781: Tor Jonson, 'The New Basis for Assessment of Forest Property', *id.*, p. 795; cf. also v. Spiegel below.

⁴ *F.C.*, 1924, pp. 297, 333.

actually realized on forest capital¹ is the index most commonly used in comparing the financial attractiveness of various silvicultural methods.

This method was used as early as 1884 by Bretschneider² and has recently been applied by Voss³ to Scots pine plantations in Prussia. The latter author showed that qualities II, III, and IV actually yield about 2.5, 2.3, and 1.7 per cent. on the money invested in them on a rotation of 100 years, and would yield rather higher rates on a rotation of 70 years for 2nd and 3rd qualities. A more detailed investigation of the returns from quality class V forests⁴ showed that at 100 years (the financial rotation) the yield was 1.06 per cent. and at 120 years (the more usual rotation) it was 1.03 per cent. This is on the assumption that the cost of land is 74 marks, the cost of planting 147 marks, and the annual maintenance cost 9 marks per hectare. If it were possible to obtain complete natural regeneration at no cost—even if the regeneration took four years—the financial yield would be 1.32 per cent. on a rotation of 120 years. From these figures Voss concludes that it is much better to adopt a long rotation if it can be followed by natural regeneration than to shorten the rotation in the hope of obtaining a higher return. On financial grounds this conclusion is open to criticism. Even assuming Voss's silvicultural premisses, an owner might be much better off if he felled plantations at 100 years and invested proceeds that were not used for replanting at 5 per cent. His financial position at 120 years would probably be stronger than if he had left his plantations standing.

FINANCIAL AND OTHER OBJECTS OF MANAGEMENT.

We are now in a position to discuss some of the more modern phases of the soil rental controversy. It is now generally admitted, even by the opponents of the theory, that, in its widest sense, the soil rent forms a sound basis for estimating financial returns and that private owners must be expected to manage their forests according to its dictates.⁵ But these opponents lay great stress on the objects of management, other than financial, which must be considered in State forests. What they chiefly object to is the short rotations which are demanded by the soil rental theory. Against the introduction of shorter rotations it is claimed (1) that the soil will deteriorate, (2) that large timber cannot be produced, (3) that the total production will be reduced, (4) that the forests will not carry such a large store of timber.⁶ Thus Lemmel says that the motto of the State forester should be 'German forestry must produce, cost what it will'. If more timber is required for industry, more capital must be invested in forestry either by increasing the forest area or by lengthening the rotation;

¹ This is the same as the 'mean annual forest per cent.', a term to be avoided, partly on account of its length and partly owing to a fallacious formula which has been attached to it by Endres (*Lehrbuch der Waldwertrechnung u. Forststatik*, 3rd ed., 1919, p. 209) and Schlich (*Manual of Forestry*, 5th ed., 1925, p. 142).

² Quoted in Lorey's *Handbuch*, 1912, vol. iii, p. 27.

³ *Z.f.F.u.ſ.W.*, xlviii, 1916, p. 505. This method was also used by the present writer in comparing returns from Scots and Corsican pines (*Oxford Forestry Memoir*, No. 6, 1926).

⁴ *Z.f.F.u.ſ.W.*, lvi, 1924, p. 616.

⁵ Lemmel (*Z.f.F.u.ſ.W.*, lvii, 1925, p. 65), Wobst (*F.W.S.*, xii, 1924, p. 133), and Eberbach (*Z.f.F.u.ſ.W.*, lvii, 1925, p. 357). Mang (*F.W.S.*, xii, 1924, p. 9), however, does not admit this.

⁶ These views are widespread. Among authors advancing these views who have not already been referred to are Fieser (*A.F.u.ſ.Z.*, 1924, p. 251), Lemmel (*Z.f.F.u.ſ.W.*, lvii, 1925, p. 65), and H. W. Weber (*F.W.S.*, xiv, 1926, p. 377).

but Lemmel admits that times like the present, when there is a shortage of capital, are not favourable for increasing forest capital. Gribkowski¹ attempts to work out the proportions of different timber sizes used in the industry and maintains that forests should be managed in such a manner as to yield sizes in the proportions required. He advances calculations to show that with heavy thinnings this can be done on the financial rotation.

The most outspoken protagonist for the rationalization, on economic lines, of German forestry is the Prussian Landforstmeister Trebeljahr, whose cogent papers are having a very salutary effect on the German literature. By the strength of his convictions, by the clarity of his style, and by his untiring vigilance in the correction of error, he is raising the plane of discussion to a higher level and, though his readers may not agree with his conclusions, they cannot fail to be impressed by his logical directness. In a paper published in 1924² Trebeljahr advances the case for shortening the rotation in the Prussian pine forests. He is careful to admit that in the management of State forests considerations other than financial have to be taken into account and, in particular, that the soil fertility must be maintained, but he insists that when financial sacrifices are made definite compensations must be secured. The compensations derived from the customary prolongation in the rotation of the Prussian pine forests are entirely illusory. Firstly, the proportion of large timber required is not so great as formerly and the percentage rise in price of small timber is greater than that of large timber. This he ascribes to the use of substitutes for large timber since prices have risen, and the best substitute for large timber is iron or small timber. Secondly, long rotations do not improve soil fertility. With a very wide knowledge of pure pine forests he is convinced that 'the older they become, so much the more does the soil condition become removed from the optimum, so much the more does it become hardened, so much the more do bilberry, heather, sedge, etc., come in, so much the thicker becomes the layer of raw humus where the soils tend to such, and so much the less is there a prospect of natural regeneration'.³ Further, where natural regeneration under partial canopy is obtained, it is so slow in growth that more harm is done by soil exposure than with clear felling and planting. These generalizations apply to pure spruce as well as to pure pine. He recommends that beech should be introduced when conifers are planted and that the rotation should be gradually reduced until the prices of large and small timber are proportional to the costs of production. 'We have so far, without valid reason, meddled too much with raising big timber and have left the rational production of small timber to an unnecessary extent to foreigners.'⁴

As is natural, the opponents of the soil rental theory have made frequent references to the condition of affairs in Saxony, where owing to Pressler's teaching and Judeich's administration 'rational management' was adopted about 1870. The condition of the forests shows that considerable soil deterioration has occurred and the present annual yield is little more than 60 per cent. of

¹ *F.C.*, 1924, pp. 297, 333.

² 'Rationelle Forstwirtschaft', *A.F.u.J.Z.*, 1924, p. 166.

³ See also Martin (*T.F.J.*, lxxvi, 1925, p. 216) for the view that long rotations are in general inimical to natural regeneration.

⁴ Under Trebeljahr's E.B.R.A. (supplemental working plan instructions) the rotation in pine is to be reduced to about one hundred years. This is much criticized by R. Hausendorf (*Z.f.F.u.J.W.*, lvi, 1924, p. 607) and others.

what it was in 1904 to 1913. Bernhard,¹ until recently Saxon Landforstmeister, has said that Saxon forestry is 'bankrupt' and ascribes this in part to the soil rental theory. Gretsche² gives an historical survey of Pressler's intervention and subsequent changes in growing stock and yield, and, though his figures have subsequently been shown to be very inaccurate and misleading³ so that his condemnation of the Saxon system can carry little weight, his picture of Saxon administration is enlightening. His view is that administration in Saxony became more efficient and mathematically perfect than in any other part of Germany, but 'where there is light there is also shadow', and this efficiency led to too much interference from head-quarters and too little consideration for the silvicultural requirements of particular localities. With this came standardization and, in particular, the expansion of pure spruce woods.

In support of the Saxon administration we have papers by Trebeljahr⁴ and Wiedemann⁵ which may be briefly summarized. The growing stock is only about 4 per cent. below the normal for an 85-year rotation and this small shortage is due chiefly to overcutting between 1893 and 1913 owing to nunmoth (Trebeljahr), overrating increment, the financial crisis of 1900, the bad snow-break of 1905, and to reduction of growth lately (Wiedemann). There has been practically no increase in the area of pure spruce since 1870, and though the rotation is, according to Wagner, the most favourable for natural regeneration, this has failed to occur owing to unknown causes. Every one agrees that some change must be made in silvicultural treatment, but it is not clear that lengthening the rotation will help matters. Trebeljahr points out that on her short rotations Saxony has built up a valuable paper industry.

The 'bankruptcy of Saxon forestry' is one of those catch-phrases which are regrettably frequent in German forest literature. If the forests were valued in 1860 and again to-day and if all outgoings and incomings were brought forward at 3 per cent. compound interest, it is likely that the Saxon forest account would be found to be less bankrupt than that of any other State; and we have yet to see an estimate of the loss incurred in Baden and other States through quite needless neglect of thinning due to too conservative management.

A view which finds frequent expression in recent literature⁶ is that the soil rental theory is applicable to a plantation, starting from bare land and managed by intermittent working; if, however, we start from an existing forest, the annual expenditure will be covered by annual income and there will be no need to charge compound interest on money invested in planting and management, since these become part of the current costs of upkeep. For this reason 'the whole is not equal to the sum of its parts'.⁷ This view becomes more explicit when it is shown that, if a forest yields a sustained net annual income equal to I ,

then the sale value of the forest will be $\frac{I}{0.0p}$ where p is the rate of interest which

the purchaser demands.⁸ By good management the income may be gradually raised so that very good returns can be obtained from forestry.

¹ *F.W.S.*, xii, 1924, No. 47 (I have not seen this paper).

² *F.W.S.*, xiii, 1925, p. 89.

³ See Bernhard, *F.W.S.*, xiii, 1925, p. 249, and Wiedemann, *id.*, p. 305.

⁴ *F.W.S.*, xiii, 1925, p. 33.

⁵ Wiedemann, *id.*, pp. 297, 305.

⁶ Principally Ostwald, *F.W.S.*, xiii, 1925, p. 110 and earlier papers; among others, Hausendorf,

F.W.S., xii, 1924, p. 185.

⁷ Kreiger, *T.F.Ź.*, lxxiv, 1923, p. 281.

⁸ e.g. R. Liefmann, *A.F.u.Ź.Z.*, c, 1924, p. 239; Sven Petrini, *Skogen.*, xii, 1925, p. 177 (quoted in *Bot. Abst.*, xv, p. 79).

The above slogan has just enough truth in it to be dangerous. Every one knows that in large forests economies can be practised that are impossible in small ones and these will reduce costs per acre and may increase sale values. Thus different figures have to be introduced into the formulae. But if a separate account is kept for each compartment the finance of the whole must reproduce the summation of these various accounts.

Godbersen has suggested that if we were purely economic we should never invest money in regeneration since it could be better invested elsewhere.¹ This, of course, is the reason why, taking the world as a whole, devastation is the most widely practised silvicultural system. The economic reason why American forests are even now being exploited so rapidly is that many people who become possessed of forests find that they can make more money out of them by felling all mature timber and realizing the remainder as soon as it is large enough than by taking the long view of the forester. In other words, the realization value of a forest is generally higher than the value calculated from the formula $C = \frac{I}{0.0p}$ if p is more than 4 per cent. These are facts which it is fatal to ignore and it is particularly surprising to find misrepresentation about them in America² where they are so fully exemplified.

If, however, a government is able, by legal enactment, to compel forest-owners to regenerate their forests, then the economics are changed. The cost of regeneration becomes an enforced deduction from the receipts from felling, so that the net realization value of the forest is reduced. Such a law would thus raise the rate of interest obtainable from forest management, not by increasing the income but by lowering the market value of the growing stock. If legislation goes farther and enforces sound silvicultural treatment after regeneration, then the sale value of the forest is reduced to the capitalized value of its annual net yield. Under such circumstances fines might be exacted if regeneration and subsequent management were not attended to and, since the payment of such fines could not be regarded as investment, it would be reasonable to maintain that the amounts spent, as an alternative, on regeneration and management should not be subject to compound interest in forest accounts. We should then approach to Ostwald's forest rent theory under which interest is not charged on these amounts.³

Even under the conditions visualized in the last paragraph a forest manager would have to choose between more or less expensive methods of regeneration and after-treatment, between increasing and reducing his growing stock, and other alternatives. In all such cases he would have to balance present expenditure against future returns and to do so he must use compound interest, employing some formula of the character of the Faustmann formula. Thus the principle of the soil rental theory is applicable to all cases, though modifications in the method may be necessary under certain circumstances.

THE FINANCIAL EFFECT OF HEAVY THINNINGS.

There appears to be some chance of a working compromise between the upholders of the soil rental and forest rental theories through the adoption of

¹ *Theorie der forstlichen Oekonomik*, Neudamm, 1926, p. 74. Eberbach (*F.W.S.*, xiv, 1926, p. 393) regards this as the *reductio ad absurdum* of the soil rental theory.

² e.g. Ward Shepard, 'The Bogey of Compound Interest', *Journ. of For.*, xxiii, 1925, p. 251; H. H. Chapman, *Forest Finance*, New Haven, 1926.

³ *T.F.ŷ.*, lxxvi, 1925, p. 153; *F.W.S.*, xiii, 1925, p. 10, and earlier papers.

systems of heavy thinning. The inspiration for this movement came largely from the astonishing results reported by Bohdannecky from early and heavy thinnings in Czechoslovakia, and though Schwappach¹ has been unable to reproduce the high volume increments claimed by Bohdannecky he found that, owing to greater diameter increment, heavy thinnings hastened the increase in value. At the same time more is realized from early thinnings so that the capital invested in the forest is lowered.

Calculations to show the influence of heavy thinnings on forest finance have been made by Engler,² Künanz,³ and Gribkowski,⁴ who have obtained very striking results. Engler's figures relate to actual sample plots in the Sihlwald and elsewhere in which comparative thinnings of grades *A* to *D* have been carried out. His calculations are made with Kraft's indicating per cent. formula and below are given a few of his results:

SIHLWALD. SPRUCE: QUALITY I.

Year.		Age.	Indicating per cent. for thinning grade.			
			<i>A.</i>	<i>B.</i>	<i>C.</i>	<i>D.</i>
1889-99	. .	28-38	2.58	3.12	3.72	4.62
1899-1911	. .	38-50	2.40	2.64	3.21	3.79
1911-21	. .	50-60	3.17	3.67	3.73	4.50

OLTEN. SPRUCE: QUALITY II.

1888-99	. .	22-33	—	5.30	7.50	8.18
1899-1913	. .	33-47	—	5.91	6.00	6.92
1913-19	. .	51-57	—	5.28	5.63	6.46

Thus for quality I stands the increase in value was from 42 to 79 per cent. higher with *D* thinnings than with *A* thinnings. Similar results were obtained with beech.

Künanz bases his calculations on yield tables, partly taken direct from others and partly compiled from isolated experimental results of heavy thinnings. The following table shows the financial rotation and the gross soil expectation value⁵ under *B* and *C* grade thinnings, calculations being made at 3 per cent. interest:

	B GRADE.		C GRADE.	
	Fin. rot. years.	Se + E. marks per ba.	Fin. rot. years.	Se + E. marks per ba.
Spruce, II . . .	60	1,501	80	1,648
Pine, II . . .	60	635	90	880
Beech, I . . .	70	814	110	973
Oak, I . . .	90	870	140	1,419

These figures show that heavy thinnings not only increase the expectation value but also lengthen the financial rotation,⁶ and since on these long rotations large timber can be produced and the ground is bared only at long intervals,

¹ *A.F.u.J.Z.*, c, 1924, p. 79. Engler, *Mitt. d. Schweiz. Central. f. d. forstl. Versuchsw.*, xiii, 1924, p. 285, obtained similar results. See, however, Gehrhardt, *A.F.u.J.Z.*, ci, 1925, p. 276.

² See above.

³ *F.C.*, 1924, pp. 183, 237.

⁴ *Id.*, pp. 297, 333.

⁵ This is *Se + E*, i.e. the soil expectation value plus the capitalized cost of annual maintenance. The use of this expression—a common text-book practice—arises from the Faustmann formula.

⁶ Schwappach obtained similar results from calculations on beech. See *Die Rotbuche, Wirtschaftliche und statistische Untersuchungen der Hauptstation des forstlichen Versuchswesens in Eberswalde*, Neudamm, 1911 (quoted by Godbersen, loc. cit., p. 77).

they should satisfy the most exacting silviculturists.¹ Gribkowski obtained even more favourable results but, as Künanz points out in a subsequent paper,² the prices which he ascribes to large timber are much too high.

It is also claimed that the *Dauerwald* system of management provides a compromise between the upholders of the soil rental and forest rental theories,³ but until reliable figures can be supplied for the yield under this system no financial analysis is possible. Wagner, in particular, insists on the importance of good silviculture and, expressing his view in terms of the Faustmann formula, complains that most economists consider variations in the rotation and cost of planting, but fail to realize that the financial return is increased more by growing the most suitable races of trees under the most favourable conditions than by shortening the rotation.

COMMERCIAL ACCOUNTANCY.

One of the newest developments of economic thought in German forestry is the growing belief in the adoption of commercial accountancy as a method for testing financial returns.⁴ The papers on this subject deal particularly with the accounts which should be opened under a system of double entry and the methods of estimating capital assets. Since income and capital are both timber the income and expenditure account has little value apart from the capital account, and, for this reason, adequate forest accountancy is impossible without frequent and accurate valuation of growing stock. This raises the old trouble of what exactly is meant by the value of growing stock and various suggestions are made for meeting it. V. Spiegel suggests taking as a basis the realization value of marketable timber and the cost value of one-year-old plantations and interpolating values of intermediate ages. Actually, however, if the forest is bought, the price will probably be less than that estimated in the above manner, so all valuations should be reduced so as to be proportional to the market value. In order that accounts may not be upset by changes in the value of money, Regenstein recommends the booking of units representing, say, the final yield of a hectare of beech and converting these units to money when required. Trebeljahr thinks that, though better accountancy is now required on account of the rise in taxation, no improvements in forest management can be anticipated from it, as the soil rental theory provides all that we require for this purpose.

THE RISE IN TIMBER PRICES.

There is no suggestion in the German literature that forestry can ever pay

¹ It may be noted that when calculated on the basis of financial yield, the financial rotation is not so much protracted, and with C grade thinnings in oak calculations at 3.5 per cent. give a financial rotation of 110 years and a gross soil expectation value of 900 marks.

² *A.F.u.Ź.Z.*, cii, 1926, p. 362.

³ H. Weber, *A.F.u.Ź.Z.*, xcix, 1923, p. 121; Martin, *T.F.Ź.*, 1924, p. 247; Wagner, *A.F.u.Ź.Z.*, c, 1924, p. 120, and ci, 1925, p. 265; Fieser, *A.F.u.Ź.Z.*, c, 1924, p. 251; Hausendorf, id., p. 517; E. Wiedemann, *Die praktischen Erfolge des Kieferndauerwaldes*, Brunswick, 1925, questions the published figures of *Dauerwald* yields.

⁴ The following papers may be referred to: Bernhard, *F.W.S.*, xiii, 1925, pp. 249, 356; *A.F.u.Ź.Z.*, cii, 1926, 218, 223; Eberbach, *Z.f.F.u.Ź.W.*, lvii, 1925, p. 357; Godbersen, *Theorie der forstlichen Oekonomie*, Neudamm, 1926; Katzer, *F.W.S.*, xiii, 1925, p. 9; Krieger, *F.W.S.*, xii, 1924, p. 99; Ostwald, *F.W.S.*, xiii, 1925, p. 110; Rausch, *F.W.S.*, xii, 1924, p. 193; Regenstein, *F.W.S.*, xiv, 1926, p. 25; Schaffer, id., p. 372; v. Spiegel, *Z.f.F.u.Ź.W.*, lvii, 1925, p. 603; Trebeljahr, *F.W.S.*, xiii, 1925, p. 281.

the high rates of interest that are occasionally obtained in Britain and some of the southern Dominions. The reasons that appear with such regularity in the text-books for adopting in calculations a low rate of interest are now less frequently quoted. In particular, the view that a long term investment at compound interest is particularly attractive to investors is so definitely at variance with the experience of stockbrokers that it need no longer be referred to. The fundamental cause of the low returns from capital invested in forest cultivation is the existence of stores of naturally grown timber which can still be exploited more cheaply than timber can be cultivated. This difficulty is gradually being overcome by the rise in timber prices which is assessed in Germany at from 1 to $1\frac{1}{2}$ per cent. per annum. This appreciation in value applies not only to cut timber but to the growing stock in the forest, so that if the apparent annual income represents 3 per cent. on assessed capital the real return may be 4 to $4\frac{1}{2}$ per cent.

The validity of this line of argument is contested by Godbersen¹ on the ground that the rise in timber prices corresponds so closely with that of other commodities such as rye, pork, and butter that it must be attributed solely to a fall in the purchasing power of money; only during the period from 1885 to 1905 did the mean price of a cubic metre of wood rise relatively to other prices, and this was due to an improvement in quality as there was a great increase in the proportion of timber to firewood. Thus, though a forest-owner may get more money for his timber, he cannot buy more with this money than if all prices had remained constant.

Godbersen's conclusions on this subject will serve as a corrective to much over-sanguine speculation, but they should be accepted with the utmost caution. Thus, in support of his view, he quotes certain figures from Cassell showing that the price of timber imported into Britain fell continuously from 1871 to 1902. These figures, however, were taken from a Government Report of 1903² and refer to 'hewn timber' only, a category which has gradually deteriorated in quality until it now comprises very little more than pitwood. Corresponding figures for 'sawn and split fir' show an annual rise in price over this period of about 0.8 per cent. when compared with a wholesale price index. Further, when prices are rising, the national rate of interest tends to rise because the real rate received is less than the nominal rate. If the forest per cent. is used in calculations based on fixed prices, this is a real rate which may reasonably be below the nominal national rate.

The foregoing review attempts to give a picture of the present position of the subject of forest economics in Germany and of the controversies that are engaging forest opinion in that country. These controversies cover only a small part of the many problems of forest economics, and it appears that we shall have to look elsewhere for enlightenment on many matters which more particularly concern us. Nevertheless, the long sustained conflict between the more conservative silviculturists and the more rational economists has elicited nearly every shade of opinion that can be held on the subject, and, by a process of sifting, we may hope to arrive at a reasonable and well-founded point of view on the questions at issue.

¹ Loc. cit., pp. 22-40.

² 'Wholesale and Retail Prices in the U.K.', Parliamentary Report, 1903.

THE OAK MILDEW *MICROSPHAERA QUERCINA* (SCHW.)
BURRILL AND *ARMILLARIA MELLEA* (VAHL) QUÉL. IN
RELATION TO THE DYING BACK OF OAK

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THE dying back of oak is one of the most interesting pathological problems and also perhaps the most serious forest disease at the present time in Europe. In consideration of this, a short discussion of some of the more important papers concerned with the disease may not be out of place. It is not proposed to go into the numerous papers concerned purely with oak mildew, its systematy, and the occurrence of perithecia. Those wishing for a general description of the fungus and an account of its general physiology should consult Neger (13), who also gives a list of some susceptible and immune species of oak. Wilson (18) also gives a short summary of information on the subject, largely taken from Neger. Buchheim (4) describes the fungus and discusses its systematy; he also confirms, as a result of infection experiments, Neger's work showing that the mildew is parasitic on beech, though at present to a much less extent than on some species of oak. Petri (15 and 16) shows that besides overwintering in the buds, the fungus perennates on dead oak-leaves. He proved this by placing pieces of last year's infected leaf on to young uninfected leaves in the spring. There were no perithecia on the old leaves and the hyphae and conidia were dead, yet he succeeded in infecting the new leaves. He considers that here the fungus perennated by means of reduced chlamydospores, hyaline, sphaeroidal, thick-walled cells to be found on the dead leaves. He considers that these chlamydospores are a further development of the spherical swellings found by Ferraris, whose paper is referred to by Neger. Should Petri's results be confirmed, then the mildew has three means of overwintering, viz. its perithecia, the chlamydospores, and the mycelium in the dormant winter buds. The perithecia do not yet appear to have been discovered in this country, and the importance of Petri's chlamydospores as a means of overwintering has yet to be determined.

Although a number of species of oak are susceptible to the mildew, the only one of commercial importance to be seriously affected is the pedunculate oak, *Quercus pedunculata*, and this is the species referred to unless otherwise stated. The pedunculate oak is not only the species most affected by mildew, but is also the one which has been dying off in great numbers in various parts of Europe.

The sessile oak (*Quercus sessiliflora*), the other principal species so far as forestry is concerned, is much less susceptible, partly owing to its relative immunity from defoliation by caterpillars and therefore from the severe attacks of mildew that follow on the 'summer shoots'. However, if sessile oak be grown as coppice, it may be seriously affected, and it is perhaps in coppice that mildew acts more than elsewhere as the principal factor in causing disease. This is well illustrated in two papers by Doé (5 and 6), who does not make it clear which species of oak he is dealing with, but presumably he is principally concerned with sessile oak.

He complains of the great damage done to the coppice woods of north-east France, and in particular those of Champagne and Burgundy. Here mildew has not only caused general degeneration of the oak stools, but has prevented natural regeneration by reducing the acorn crop and attacking those seedlings that do come up. On this account, when after some years the weaker stools die, other species, such as ash, elm, poplar, and hornbeam, tend to take their place. The picture he draws is, to say the least, mournful; Klimesch (11) writing of Dalmatia gives the same description of the oak coppice in that region. The chief recommendation Doé has to make is that the oak coppice should be allowed to grow up into high forest. In this he is influenced by experience in the sessile oak forests in the west of France. Aubert (1) in a short paper shows that in this part of France, although the oak has been attacked by mildew to a greater or less extent, the crops of acorns have been more than sufficient for regeneration, and neither the young nor the older stands have been appreciably affected by mildew. He ascribes this to the practice of a suitable silvicultural system, and condemns coppice woodlands as bringing about a physiological weakening of the trees, causing them to lose their power of resistance to disease. In this he compares them with the pollarded and lopped trees so common in Normandy: where these trees have been oak, the mildew has apparently caused great damage, with the result that many have died after a few years' successive attack. It is worthy of note that both Doé and Aubert are dealing with sessile oak (*Quercus sessiliflora*). This species is much less liable to defoliation by caterpillars, and to the heavy attacks of mildew that follow such defoliation. In this is to be found the reason for the relative immunity of the high forests of western France, and for the hope of success in preventing future damage by mildew, by converting the coppice to high forest. In Dalmatia, where Klimesch is concerned with pedunculate oak, such treatment might easily not be so successful as desired.

The dying back of oak coppice may be left without further consideration, for the system has lost much of its importance in recent years; besides, the chief losses due to dying back have occurred in high forest. Here one deals almost entirely with the pedunculate oak: losses in sessile oak do not appear sufficient to be mentioned. The disease in high forest is first recorded by Klimesch (11) and Georgévitch (10) as occurring sporadically, but to a sufficient extent to be noticed, in 1902 in Slavonia (Jugo-Slavia), in the forests on the plain of the river Save. It does not appear to have been investigated at this time, but it is interesting to note that at this date oak mildew had not appeared in Jugo-Slavia, nor, so far as is known, in Europe, and therefore that the dying back could not have been complicated at that time by this fungus. Klimesch, who gives the fuller description of the disease, states that the dying back increased from this date, but only became severe after the appearance of the mildew. According to him, three periods during which the disease has been worst are 1909-12, 1916-19, and 1920-3. From Yussifovitch (19) and Georgévitch one learns in addition, that whereas in 1910-11 relatively few oaks died, in 1911-12 the disease assumed great proportions.¹ The dying back has occurred irrespective of soil quality or moisture content, but it is important to note that whereas pure oak stands have suffered severely, mixed stands, and

¹ Yussofovitch (1926). In the commune of Brod 765 trees died in 1910-11, and 172, 663 in 1911-12.

especially those in which the oak forms 50 per cent. or less of the mixture, have escaped with little or no damage. The mixtures referred to here are oak and ash; oak, elm, hornbeam, and ash; oak and alder, and oak and aspen, according to the locality. This is a most important point; and that mixed stands shall be maintained is, perhaps, the most effective recommendation that Klimesch makes for the prevention of the disease.

Most authors agree as to the several factors which, acting together, cause the dying back; the only difference is that some stress one factor more than another according to their experience and bias. The general sequence of the disease is best followed in Falck's papers (7 and 8). According to him the foundation of the disease is laid in a physiological weakening of the tree. This was produced, in the cases that he investigated, by defoliation by caterpillars and drought. The next step is the infection of the tree by the primary parasites; these are oak mildew, which is the chief one concerned, and also Buprestid larvae, boring in the stem. This primary infection does not result in the death of the tree but only in its further weakening; but when very severe the tree may die down to the roots, which, however, remain alive unless otherwise affected. The severity of mildew attack upon occasion may be estimated by the fact recorded by Klimesch, that sometimes a second complete defoliation is produced by its agency. Klimesch considers that the fate of the tree is chiefly determined in these first two stages; if severe defoliation by caterpillars is followed by severe mildew attack, itself resulting, perhaps, in at least a further partial defoliation, then it may be considered that dying back will probably take place. He does not, like Falck, mention drought as being a first cause of the trouble, but it is noteworthy that in many parts of Europe during the years 1901, 1911, 1915, and 1921 drought occurred, and that some authors: (Falck, 7, 8), Baumgarten (3), Baltz (2), Robinson (17), definitely consider drought as sometimes one of the principal factors in the disease. It would be interesting to know if there is any evidence that this might be the case in Jugo-Slavia. Falck's last stage, in which the death of the tree occurs, is brought about by secondary parasites. These are fungi, species of *Dermatia* and *Clithris*, which attack the bark of the crown, and *Armillaria mellea*, the honey fungus, attacking the roots. If these parasites could be excluded Falck considers that the trees would recover, to a very great extent; if *A. mellea* is excluded, then the roots may still survive and throw up stool shoots in the following year. In reality these fungi are nearly always present, and *A. mellea*, being the most conspicuous as well as the most dangerous, has received perhaps more than its share of credit as a cause of the disease. Examination of the authors quoted shows that a very considerable difference of opinion exists as to the real importance of this fungus. Georgévitch and Baltz appear to consider it as being the most dangerous of any of the factors involved, and evidently regard it as a virulent parasite under the conditions involved. The other authors, on the whole, tend to regard it more as killing off trees irretrievably damaged in any case. Seeing that honey fungus does not even appear to be virulently parasitic on oak except under such circumstances as have been described, this view is probably the correct one.

When it is considered how the dying back of oak is to be prevented, the real difficulties begin. It is obvious, of course, that small trees, especially in the nursery, may be treated by spraying or dusting. This treatment is relatively easy, but that of high forest is less obvious. A zoologist such as Gasow (9) is

concerned with the combating of caterpillar epidemics, and discusses bird protection and the possibility of direct attack by spraying or dusting high forest. The latter can be done, but is, of course, exceedingly expensive and not necessarily effective. Most authors, while suggesting minor or partial remedies, such as the spraying of small nursery plants for mildew, are content to stress the necessity of further research in order to find means of fighting any or all of the factors involved. One thing that does seem to arise out of a general consideration of the subject is that, however useful a direct attack may be in connexion with nursery plants, or young plantations or regeneration, it is not going to achieve any real success in high forest and probably will be never attempted except as a last resource. Here indirect silvicultural measures are preferable. Klimesch's suggestion that all oak stands to be established should be mixed is well worthy of consideration and of trial. That it would prove successful in this country is made probable by Osmaston's (14) experience; and his suggestion that even-aged mixture is better than oak with underwood would seem also to be sound. In this country beech is probably the best species for mixture. On account of the relative immunity of sessile oak as compared with pedunculate, this species is to be considered preferable for new plantations. If the experience of Klimesch and Osmaston with even-aged mixed woods is generally repeated, it would appear that in their establishment lies the solution of the problem, and that by this means pedunculate oak will be preserved as a useful forest tree. The advantage of mixed woods would appear to be: first, that caterpillar ravages are not nearly so serious, and that therefore mildew attack is also less severe; and that even if severe defoliation and mildew attack should occur the admixed species, e.g. beech, remains to help to cover the ground and prevent the rapid and obnoxious development of weeds and general deterioration of the soil.

If the pedunculate oak is to be preserved as a valuable forest species, there is another point that may have to be studied: this is the relation between the date of leaf development and caterpillar attack; for, as is well known, the later an oak bursts into leaf the more liable it is to defoliation and subsequent attack by mildew. This point is very well illustrated by Molleveau (12) in writing on the dying back of oak in the forest of Vierzon. In this forest there are three varieties of oak, the sessile oak (*chêne rouvre*), an early pedunculate oak (*chêne pédonculé hâtif*), and a late pedunculate oak (*chêne pédonculé tardif*). The latter is also called *chêne de juin*, from the month in which leaf development begins, and is particularly suited to some parts of the forest. This late variety is very liable to defoliation, and in 1922 and 1923, after the drought of 1921, suffered with great severity from attack by caterpillars and afterwards mildew. Many of these trees died back as a result of this, the early (*hâtif*) variety suffered to a much less degree, and practically none of the sessile oak were affected. No clearer illustration could be had of the advantage of an early variety of pedunculate oak in combating the present widespread dying back.

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REVIEWS

Erweiterte Denkschrift über die Bedeutung der Fadenpilze für die Nutzbarmachung der Abfallstoffe zur Baumernährung im Walde und über die Möglichkeit einer nachträglichen pilzlichen Aufschliessung des Trockentorfs. R. FALCK, *Sond. aus Mycol. Untersuch. u. Ber. Cassel*, 1923, p. 38.

(*Extended memoir on the importance of fungi in rendering organic detritus available for the nutrition of forest trees and on the possibility of a subsequent decomposition of dry peat by mycelium.*)

A Review by M. C. RAYNER, D.Sc.

THERE is no more fascinating chapter in the story of soil investigation than that relating to the cycle of changes undergone by plant and animal residues.

The manner in which the contained nutrients become available to vascular plants has long been recognized as a soil problem of the first importance. Earlier, it was the subject of many more or less speculative theories; in recent times, it has attracted the attention of a growing number of research workers. It assumes special significance in woodland soils where the ordinary cultural operations do not find a place, and in which—as is pointed out in the paper now under review—the annual deposition of a mass of vegetable detritus represents a manurial dressing of high potential value, capable of providing all the essential nutrients required for healthy growth. In the case of ordinary cultivated soils the whole of this nutrient material is removed with the crop; in woodlands such loss is confined to the timber removed by felling.

It has long been known that the release of the nutrient constituents bound up in humus depends upon intricate biological processes; it is likewise evident that a high proportion of these substances must be utilized by woodland trees; yet relatively little is known of the details of the process, or of the conditions which promote and ultimately determine the formation of one or other of the widely different types of humus soil.

Although the subject is not necessarily or immediately concerned with the mycorrhiza of trees, it is closely bound up with the activities of fungi as members of the soil microflora and hence comes into touch with the ecological and physiological aspects of root infection.

In two earlier papers Falck (1906) published an account of the changes induced during the fungus decomposition of manure, and traced the origin of the carbon dioxide and nitric acid produced. In the present memoir he summarizes the results of researches bearing on the decomposition of woodland humus. His observations and experiments were directed to ascertain the exact cycle of changes by which the nutrients locked up in the humus of woodland soils are released, to examine the causes underlying the accumulation of the latter in a relatively undecomposed state to form dry peat (Trockentorf), and to test the possibility of artificially inducing the breakdown of this resistant material by biological methods.

As an initial step he was led to the conclusion that poverty in nutrients and the resulting deterioration of forest soils due to excessive accumulation of raw humus are due to the absence of a normal fungus flora. Experiments confirmed the view that the members of this flora, in particular Hymenomycetes and

other Basidiomycetes, are extremely effective agents in the decomposition of cellulose and woody tissues.

In fertile forest soils the appropriate fungi are present, and the yearly accumulation of leaves, twigs, roots, and woody detritus undergoes rapid and complete disintegration. Falck discusses the chemical changes involved in this progressive decomposition to which he has given the name *mycocriny* (Mykokrinie).

In nature it frequently happens that this process, initiated by fungi, is interrupted by the depredations of insect larvae—especially flies and beetles—which devour the partially decomposed masses of organic material together with the mycelium which permeates it. After digestion the products are excreted as a friable, dark-coloured humus material subject to further degenerative changes by ‘humification’ bacteria whose activities probably begin during the active life of the larvae.

This threefold type of humus decomposition Falck has named *anthracriny* (Anthrakrinie). It results in the liberation of the bulk of the nitrogenous and mineral nutrients together with the formation of a humus substance beneficial to the physical condition of the soil, and is believed to be the process responsible, in nature, for the formation of humus soils of the neutral type (Mullboden), which, in Falck’s opinion, provide the optimum conditions for tree growth. Careful examination of such soils has shown the existence of four distinct layers: (a) an uppermost layer of unaltered leaves, &c., thickest in autumn and reduced to inconsiderable proportions in spring; (b) a zone of fungus activity consisting of partially decomposed humus matted and interpenetrated by mycelium and very resistant to the leaching action of rain, easily recognizable in spring and summer but difficult to find at other seasons; (c) the characteristic ‘mild’ humus layer consisting below of dark-coloured insect excreta and passing by imperceptible stages into the layer above; as compared with peat humus, this layer is relatively rich in insect life and in bacteria; (d) the upper layer of mineral soil containing the soluble materials leached from the overlying deposits, and penetrated in all directions by the absorptive root system of the trees that may extend upwards into the overlying humus layers. Where mycocriny rather than anthracriny prevails, there is found, below the last year’s leaf fall, only a thin fungus layer representing the residues of the previous year, and this passes more or less directly into the unaltered mineral soil beneath.

The beneficial results ascribed to anthracriny are stated to be increased by the liberation of a steady stream of carbon dioxide from the breakdown of organic compounds. Owing to the existence in woods of light air currents in even the calmest weather, this is brought continuously into contact with the leaves, so increasing the percentage of this gas available for assimilation.

In sharp contrast with mycocriny and anthracriny is *anthrageny*, the accumulation of humus in a relatively ‘raw’ state to form peat (Trockentorf). Peat formation is brought about by absence of the appropriate fungi or by the existence of conditions unfavourable to their activity. The mass of raw humus undergoes partial decomposition accompanied by ‘humification’, the chemistry of which is stated to be obscure. Observed as a whole, the carbon compounds undergo condensation with corresponding loss of water and darkening of colour, the nitrogenous and mineral constituents persist in forms inaccessible for nutrition, and any soluble substances produced are easily washed out by rain.

In natural woodlands the various types of decomposition described are not sharply marked off from one another and transitional conditions may often be observed. Moreover, the onset of unfavourable conditions may cause anthracriny to pass into anthrageny, or factors may operate to bring about alternating periods of one or other type of action.

The contrast provided by these different kinds of decomposition in respect to the liberation of plant food is sufficiently striking. Yet, as Falck points out, it is not always accompanied by a correspondingly sharp difference in the vegetation. On the contrary, many tree species appear to grow quite satisfactorily on peat or other humus soils in which no progressive decomposition is taking place. This result is explained by an appeal to the mycorrhizal habit characteristic of a majority of forest trees.

Defining *mycotrophy* as the *capacity to assimilate organic compounds through the agency of specific root fungi*, Falck reviews the historical evidence bearing on the significance of mycorrhiza in the nutrition of vascular plants, and discusses his own experimental results in respect to that of trees. Independently, he has reached the conclusion that mycorrhiza formation and the mycotrophic habit are of the first importance to trees growing in humus soils, the benefits resulting therefrom consisting solely, in his opinion, in the presentation to the trees of all the requisite food-stuffs (including carbon) in the form of organic solutions, and not, as in the case of the nodule-forming associations in *Eleagnus*, *Alnus*, and other trees, in the fixation of atmospheric nitrogen.

Among the experiments carried out in attempting to obtain confirmation of this view were some in which young pines with active mycorrhiza were grown in closed vessels supplied with a continuous stream of carbon-dioxide-free air. These showed stronger and better sustained growth than did similar seedlings either in a fungus-free substratum or in one deprived of organic material. It was concluded that trees furnished with mycorrhiza could obtain the requisite supplies, not only of nitrogen and mineral salts, but likewise of carbon, in the form of organic solutions.

Discussing the significance of mycocriny, anthracriny, and mycotrophy as compared with anthrageny in relation to silviculture, Falck expresses the opinion that anthracriny is the most favourable type of decomposition, alike in woodlands and in cultivated soils. It provides all the essential nutrients in an available form, and does so continuously and abundantly during the period of maximum growth, at a season when the risk of loss by leaching is least. The most unfavourable condition in woodlands is anthrageny. The masses of peat which accumulate represent the nutrient capital for tree growth in an inaccessible form and produce, at the same time, an injurious effect upon the underlying mineral soil. Under natural conditions, however, these adverse effects are minimized by the mycotrophic habit due to the possession of mycorrhiza. Incidentally, Falck provides experimental evidence that the mycorrhizal fungi of trees are less sensitive to the effects resulting from the accumulation of raw humus than are those responsible for the breaking-down processes in mycocriny and anthracriny, although his results in respect of this are admittedly incomplete.

The application of Falck's conclusions to silviculture and their interest for students of forestry appear to the writer to be bound up with aspects of the subject such as the following:

1. The nature of the factors favourable to mycocriny and anthracriny.

2. The support or otherwise derived from modern experimental studies of tree mycorrhiza for the view reached respecting the physiological role of mycorrhiza in tree nutrition.
3. The possibility of bringing about the decomposition of peat artificially, by means of fungal activity.

With respect to the conditions favouring mycocriny and anthracriny rather than anthrageny, full information is not yet available. The following provisional conclusions have been reached:

A low soil temperature during the summer is favourable to peat formation, while air humidity associated with a higher soil temperature encourages fungal activity. High water content favours peat formation and an adequate supply of lime promotes decomposition and neutralizes the organic acids incident to fungus growth. The existence of a suitable and abundant fungus flora is evidently a formal condition for mycocriny and anthracriny, and the condition of the debris is of some importance, e.g. tightly packed needles are more resistant to attack than is more loosely arranged material. The latter point provides Falck with an argument in favour of mixed planting of different species of trees.

The opinions expressed respecting the role of mycorrhiza in trees are in complete agreement with those reached recently by Melin, following an exhaustive study of the mycorrhiza of pine, spruce, and other conifers as well as certain deciduous trees (Melin, 1923, 1925). Space does not permit a review of these researches, but their bearing on the matter under consideration is clear from Melin's main argument, namely: 'dass die Mykorrhizen für die Pflänzchen und Bäume auf Rohhumusboden und verwandten Bodentypen eine vitale Bedeutung besitzen.'

It remains to inquire whether these theories of humus decomposition—mycocriny and anthracriny—and of humus consumption—mycotrophy—afford new possibilities for utilizing the reserves of plant food locked up in peat. With respect to this Falck has, as yet, only tentative suggestions to offer, and the whole subject calls for further experimental study. It is suggested that anthracriny might be induced by the introduction of suitable fungus species, e.g. by methods similar to those practised in the cultivation of mushrooms. It is significant that Melin has reached similar conclusions respecting the need for experimental researches on the control of mycorrhizal activity in forestry practice. The whole subject offers a fascinating and practically untouched field for intensive study.

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(*Research on the role of tree mycorrhiza: a physiological-ecological study.*)

A Review by E. V. LAING.

THIS comparatively recent publication by Melin must rank as one of the most valuable and important contributions to our knowledge of the living tree, and more particularly to our knowledge of that intimate union of fungus and tree root which is called mycorrhiza. This account of Melin's researches may be divided into four parts: (1) that dealing with the identity of the fungi forming mycorrhiza, their specialization, and capability of forming true mycorrhiza; (2) that dealing with the behaviour of these fungi known in pure culture apart altogether from their commensal partners—the higher plants; (3) the tree apart from the fungus; (4) the tree together with the fungus.

Melin has been able to establish the identity of many fungi which form mycorrhiza. Those identified so far belong almost exclusively to the Hymenomycetes. He has evidence—and the research of other investigators such as Peyronnel, McDougall, and Masui would tend to corroborate Melin's findings—that the mycorrhizal fungi are species of *Boletus*, *Amanita*, *Cortinarius*, *Lactarius*, *Russula*, *Tricholoma*. Species of these genera are capable in varying degrees in pure culture of forming mycorrhiza. Some are highly specialized, such as *Boletus elegans*, which is confined to one species of tree, namely, the larch: others are less specialized, such as *Amanita muscaria*, which may be found on spruce, larch, pine, and birch; whilst others, such as *Boletus luteus*, are capable of forming mycorrhiza only on conifers. In addition to these known organisms, certain fungi have been isolated from tree roots, but have not so far been classified. These fungi are termed *M.R. (Mycelium radices) abietis*, *M.R. silvestris* α , β , γ , δ , and can when brought in contact with the sterile roots of tree seedlings form mycorrhiza. It is of importance also to note that two harmful fungi, *Rhizoctonia silvestris* and *M.R. atrovirens*, have also been isolated from tree roots.

As regards the fungi themselves it seems clear that most of the groups of humus Hymenomycetes which form mycorrhiza are obligate parasites. They cannot be cultivated on artificial media when some substance secreted by roots is absent. Phosphatide has been shown to be secreted by roots and can be obtained from germinating seeds. All the mycorrhiza-forming fungi develop much more successfully in the presence of phosphatide than where it is absent. *Boletus variegatus*, for example, has fourteen times stronger growth with than without phosphatide. Not only mycorrhizal fungi but soil fungi in general benefit from phosphatide, e.g. *Mucor ramanniana*—a fungus common in soils. Phosphatide acts in very minute quantities, and is of the nature of an enzyme or vitamine. It fails to act either as a source of nitrogen or carbon for the fungi.

In addition to this interesting discovery of the stimulation of fungal growth by means of phosphatide, Melin further examines and determines (1) the reaction of various mycorrhizal fungi to changes in the pH value of the medium; (2) the relation of such fungi to nitrogen; (3) the carbon supply of the fungi.

The best growth of the mycorrhizal fungi is obtained as might be expected, on an acid medium, the optimum lying between 4 and 5. Generally no growth occurs at values beyond 3.5. *Rhizoctonia silvestris* and *M.R. atrovirens*, however, possessed two points of best growth, namely, 3 and 7.

It has been frequently claimed that mycorrhizal fungi are capable of fixing free atmospheric nitrogen. Experimental work in this connexion, however, has always been rather indecisive and contradictory. Melin tested for nitrogen fixation over a wide range of fungi which form mycorrhiza, and found quite decisively that the fungi in question did not possess this valuable property.

This negative result leads to the question as to how the fungus does obtain its nitrogen and what forms of nitrogen the fungi can utilize. The tests in this connexion were most exhaustive, but the results clearly indicate that ammonium salts, with the exception of ammonium tartrate and ammonium oxalate, constitute a very good source of nitrogen for the fungi experimented with, although, owing to the destruction of the kation NH_4 , an accumulation of acid follows which soon creates an unfavourable medium. As regards the assimilation of nitrate, species are found to behave differently; for some the nitrate being very favourable, to others useless or weak, as a source of nitrogen. Growth is found to be very satisfactory where uric acid, peptone, guanin, or nucleic acid is used. The value of nucleic acid is interesting when it is considered that it is a derivative of nucleo-proteins in humus.

With different carbon compounds rather variable results are obtained, but generally glucose as a source of carbon gives the best results. Maltose in most cases is quite satisfactory, whilst a good growth of *Boletus variegatus* and *Boletus elegans* is got when dextrose and mannite are used, and of *Boletus elegans* where xylose is the carbon compound. Lactose, inulin, cellulose, starch, arbutin, and tannin prove useless or of little value. *M.R. atrovirens* and *Rhizoctonia silvestris*, however, unlike the mycorrhiza-forming fungi investigated, are able to utilize cellulose to a high degree, *M.R. atrovirens* being more successful in this respect than *Rhizoctonia*.

In that part of his research dealing with the tree seedling apart from its fungal partner, Melin again directs his main attention to the relation of the plant to the nitrogen supply. Spruce, pine, and other conifers suffer to a very great degree from lack of nitrogen. Ammonium chloride acts as the best source of nitrogen, being superior to potassium nitrate or asparagin which are suitable for both pine and spruce. Seedlings in nitrogen-free media, or in media where the nitrogen is not in an easily assimilable form, exhibit certain features which are rather suggestive of conditions in the field or plantation. For instance, the roots, where nucleic acid is used, are very much longer than where ammonium chloride is used. Variability as regards root hair development is also noted, depending on the form of nitrogen. Root hairs are most strongly developed with ammonium chloride, whilst where potassium nitrate, asparagin, nucleic acid, or peptone is used root hairs may be absent or reduced. It is a feature of conifers in the field that they may or may not produce root hairs, and this relation of root hairs to nitrogen form in pure culture is extremely interesting in providing one possible explanation of this variability in nature.

As had been found in the case of the individual organism, Melin found no evidence that in partnership as mycorrhiza there was any ability to fix atmospheric nitrogen. He therefore proceeded, as he had done with the organisms separately, to determine the relationship of mycorrhiza to various organic and inorganic nitrogen compounds, and to prove or disprove the hypothesis of such investigators as Stahl, Frank, Elenkin, and von Tubeuf that mycorrhiza assimilate the organic humus nitrogen.

With ammonium chloride as the source of nitrogen in the nutrient solution, pine and spruce develop equally well with or without fungus infection—the only difference noted being as regards length of needle and nitrogen content of the plants.

	Pine.		Spruce.	
	+ Mycorrhiza.	— Mycorrhiza.	+ Mycorrhiza.	— Mycorrhiza.
Length of needle . . .	Shorter.	Longer.	Longer.	Shorter.
Nitrogen content in mg. .	3.91	5.05	2.92	4.61

In this experiment all the infected plants had their roots infested with mycelium and there was no shortening of the rootlets, and it seems that in pure culture, in this instance, the taking up of nitrogen through the mycorrhiza is slower than through the roots alone; but the spruce, at any rate as indicated by the longer needle, cannot be damaged under these conditions by the presence of mycorrhiza.

Somewhat similar results are obtained with nitrate, although, however, the nitrogen content of the plants is lower than where an ammonium salt is employed.

The importance of mycorrhiza begins to be seen, however, when the nitrogen is supplied in some form such as peptone or nucleic acid. In the mycorrhiza plants the needles are longer, fresher, and darker green than in the non-infected, and the nitrogen content is much higher—about three times. Mycorrhiza, therefore, can utilize more complicated nitrogen compounds much more successfully than can ordinary roots alone. In addition all fungi are found not to be alike in their ability to convert organic nitrogen compounds into a suitable form for the higher plant. The fungus *M.R. silvestris*, for example, is found to be much more capable of utilizing nucleic acid than any of the others, although *Boletus luteus* and *Boletus variegatus* are quite successful in this respect.

Mycorrhiza are found to attain their best development in a medium with a pH of about 5. In all cultures, however, there is found to be a change in the pH value of the culture medium in the neutral direction, this change being most marked where nucleic acid is used (3.4–5.1), and least with ammonium chloride (4.3–4.4 or 4.5).

Two further important points require to be noted from Melin's work. The first is with reference to possible parasitism of fungi forming mycorrhiza; the second is in connexion with the observed beneficial action of mountain pine on the growth of spruce. As regards the former, Melin has not been able definitely to prove that mycorrhiza-forming fungi become parasitic in nature, but in pure culture, if the plants are weakly developed, conditions may arise where the balance between fungus and plant is upset, the fungus becomes partially parasitic, and the plants injured. In illustration of this, for instance, spruce inoculated with *M.R. abietis*, where peptone is used as the source of nitrogen, may develop a weak root system, with the side roots thickened and club-shaped, and with thick intracellular hyphae; the main root is strongly invaded by the mycelium and the mycelium proceeds even into the hypocotyl.

As regards the second point, namely, the beneficial action of mountain pine on spruce, it is generally supposed and repeatedly stated that the benefit results from the mycorrhiza of the pine being able to fix free atmospheric nitrogen. Melin, as previously noted, failed to find any fungus capable of forming mycorrhiza which could fix the free nitrogen of the air. Further, the fungi

entering into intimate union with the roots of mountain pine are, according to Melin, the same as those which occur on Scots pine, and no such stimulating action on spruce is claimed on behalf of that species. Mountain pine, therefore, must exercise its influence through some medium other than that of free nitrogen fixation.

The above notes, though brief, represent, in the writer's opinion, the salient points of a paper which is replete with information of the utmost value, not only to the investigator into problems connected with tree growth and development, but also to the silviculturist.

A Note on Hesselman's 'Barrskogens Humustacke' (Study on the Humus Covering of Coniferous Forests, their Properties, and their Relation to Silviculture). (*Report of the Swedish Institute of Experimental Forestry*, 22, 1925.)

By G. K. FRASER.

THE problem of the classification of soils and estimation of site-values is always of considerable importance and, at the present time to a marked degree, is occupying the minds of most soil investigators whether in agriculture or in forestry.

In this country only a commencement has been made in systematic grouping, but abroad a fair degree of progress has been made. This progress has followed the investigation of wide stretches of land of regularly varying topography and causal conditions (climatic, &c.), and has led to the grouping of soils into a comparatively small number of what may be described as climatogenic soil groups of world importance; the fundamental theory underlying the classification is that soil type is produced predominantly, if not entirely, by climatic conditions, whatever be the nature of its geological base, if a sufficiently long time is given for the action of this climatic process. Along similar lines has been developed in Finland, by Cajander, the well-known system of assessment of quality classes by what is termed the Forest Types (Waldtypen) method, a system which may be justly considered the natural development of the principles of vegetational ecology applied to regularly varying habitat conditions by the silviculturist.

Into the broad issues of the question of principles of classification involved it is not advisable to enter here, although both systems may be attacked on these grounds, but our main objection to both systems is that their chief scope lies in world classification or at least classification of wider areas than most soil workers can become familiar with, and that the application of either Glinka's Soil Classification or of Cajander's Forest Types to a limited area such as Great Britain must necessarily result in confusion and mistake, even although one admits the fundamental utility of both.

These reflections are suggested by the perusal of a paper bearing the above title published by Hesselman in the *Reports of the Swedish Institute of Experimental Forestry* (summary in German). Hesselman is not only convinced that Cajander's 'Waldtypen' cannot be applied to Swedish forests, but also that it is quite misleading; and he has produced good evidence for his assertions. We feel that his results may be equally well applied to Glinka's classification of soils in its application to conditions in this country as well as in Sweden.

There may be no doubt that, as Cajander maintains, 'in a Forest Type, therefore, as a rule, only those primary—climatic and edaphic—factors of

locality are reflected, which may be assumed to remain active even when the locality is laid bare of all plants,' but the crux of the question is really not whether those factors 'remain active' but whether those factors exert their activity along identical lines or such similar lines as to obliterate for all practical purposes the effects of vegetation, crop, method of treatment, and so on. It seems that there are too many large assumptions—Glinka assumes that all types of humus are (or will become under identical climatic conditions) the same, Cajander assumes that the effects of all types of vegetation, &c., upon climate are similar. Hesselman shows that both assumptions are invalid.

This paper is a continuation of earlier work into the nitrogen economy of Swedish forest soils, wherein the importance of nitrogen metabolism in the soil, as a factor of soil fertility, was fully demonstrated. From this it was concluded that a fuller knowledge of the properties and effects of acid types of humus must be obtained in order to place soil fertility problems on a more exact basis, and to classify the relationships of methods of practice to soil improvement.

Comparing Swedish soils with those of Central Europe Hesselman concludes that whereas the fertile mull type of humus (with 'brown earth' soil) is the characteristic soil covering of Central European forests, raw humus (with 'podsol') is the characteristic Swedish Northern type, a type considered a 'pathological' type by German foresters, probably the result of inefficient silvicultural operations. Can the podsols of North Sweden be changed into mull types?

In the first instance it is shown that topography may have a determinant importance in the soil itself apart from—in fact opposing—topographically determined climatic variation. For example, the downward percolation of lime-laden water from higher to lower levels in a sloping surface, removing acid constituents as well as neutralizing these, produces in place of raw humus a mull type of soil bearing a vegetation which possesses constituents found in areas where the mull type is general, upon drier rather than wetter soils; that is to say, a dynamic process conditioned by topography may produce results, so far as vegetation is concerned, equivalent to a static climatic condition totally different in its outward appearance.

Examples are also given where under different climatic conditions different or indeed diametrically opposed methods of silvicultural treatment must be used to obtain a corresponding result; for example, under the Atlantic climate of the Black Forest clear cutting is followed by rapid formation of raw humus, invasion of heath sub-shrubs, and soil deterioration; in the Norrland area (Sweden) with a continental climate raw humus is general in the old selection forests, but disappears on clear cutting, the warmth of the summer being responsible for the more rapid decay of humus; again, at higher elevations in Sweden, where high rainfall occurs and temperature is lower, raw humus occurs both in close and cleared conditions, and drastic operations such as burning are necessary to remove the raw humus so as to obtain natural regeneration. The operation, successful in one case, is directly injurious in the second and ineffective in the third; silvicultural method of treatment is sufficient to determine quality of locality against the tendency of climate and soil in some cases but not in all.

Reference is also made to soil flora and fauna in relation to their effects on humus covering and this might be extended to vegetarian fauna and their relation to vegetation and hence to the soil.

Apart from the concluding descriptions of the areas investigated the main

portion of Hesselman's paper consists of a large series of determinations of the reactions and of related data of these forest soils, their humus, leaf-litter, &c., and of the connexion existing between these and soil type, soil nitrogen metabolism, and general fertility. On the whole a case is made out for a *general* inverse causal connexion between acidity and available nitrogen in the soil, but acidity may be due to different fundamental causes producing different effects in this and other respects. Very striking are the differences shown in the leaf-litter, humus, and hence soil under different species of trees and ground vegetation, e.g. birch, pH = 5.3-6.1, beech 5.3-6.6, conifers about 4, &c., reaction in each species varying somewhat from place to place. Considerable stress is laid upon the presence in leaf-litter and humus of buffer-bodies ('Pufferstoffe') which under given conditions tend to retain their acidity and to intensify acidity, these occurring to a marked degree in species of plants which have been considered liable to show (or cause) soil deterioration, e.g. pines, heath plants, &c. Plants in which the buffering agent has a reaction of a more favourable type, such as birch, beech, and broad-leaved trees in general, counteract this acid-buffering and in turn tend to impress their reaction upon the soil; e.g. a mixture of pine and birch upon a given soil produces better soil conditions than a pure pine forest does, owing to the action of birch leaf-litter in reducing the acidity, and so with any of the broad-leaved trees. In other words the forest type is influenced in a very definite way by the artificial introduction or natural occurrence of broad-leaved 'soil improvers' in a coniferous crop—reference is of course made to beech in this connexion as the 'Mutter des Waldes' in the eyes of the German forester.

All the implications of Hesselman's paper cannot be touched upon, but the points mentioned indicate its value and great interest; it may not contain a great deal which will modify practice but it places, amongst other things, the necessary practice of including 'soil improver' broad-leaved species in a coniferous crop on poorer localities upon a more satisfactory scientific basis than has hitherto been set forth; it emphasizes the danger of the direct application of insufficiently understood silvicultural systems or methods from one climatic or edaphic region to another, only because successful in the first instance; it clearly shows that the application of vegetational ecology to the silvicultural determination of quality of locality must be undertaken with caution, especially with regard to exact numerical evaluation, since a vegetational or forest type is not such a definite and invariable entity in fact or under artificial treatment as it tends to become in the mind and with limited outlook or experience; and finally, as the author indicates, it points the way to further investigation and comprehension of the interrelations of soil and crop.

1. Aims and Methods in the Study of Vegetation, edited by A. G. TANSLEY and T. F. CHIPP, 1926.

2. The Theory of Forest Types, by A. K. CAJANDER, Helsinki, 1926.

A Note by A. S. WATT.

THE natural order is not necessarily the order in which things are studied. Man has used what lay to his hand without staying his action to consider causes and consequences. Indeed consequences have in many cases directed his attention to values hitherto unsuspected or ignored. For example, Palestine,

India, Africa, Central Europe, and America have all suffered from the inconsiderate exploitation of forests. And now excessive grazing is resulting in the impoverishment of pasture, the denudation of the land, and in disastrous soil erosion. The inconsiderate introduction of alien animals and plants—the bramble in New Zealand, the prickly pear in Australia, sparrows in America, and the grey squirrel in our own country—affords another illustration of the evil consequences of lack of forethought and the inadequate knowledge upon which we exercise our sovereignty over other living things. This is no justification of a policy of medieval speculation and inactivity, but is a condemnation of activities at present carried out by people and states ‘who ought to know better’. It also implies in a community which has reached manhood’s estate a reasonable approach to the study of biological arts whose practice in the past was founded, and is still largely continued, upon an empirical basis.

The art of growing forest depends on a knowledge of tree habits and needs, and of habitats and the interrelations between the trees and other forms of life—plant and animal—in the forest. Its foundations therefore are biology and ecology. The recognition of this broad basis is in part due to the increase and systematization of ecological knowledge which provided the needed outlook and the requisite method of approach to those problems arising from the evil results of the earlier policy. The older view was floristic; the modern vegetational.

In this country, where so much land has been disforested, the forester is denied the easy attainment of the information he wants because of the absence of trees, and is constantly faced with the problem of interpreting other types of vegetation in terms of tree growth. But his progress in the study of a plant community is generally limited by his inability to name the constituent species (how otherwise with our continental colleagues!), to analyse, characterize, and delimit it. The inquirer will find much of the information he wants in *Aims and Methods*, a book written primarily for overseas workers—agricultural and forest officers are specially mentioned—and dealing with types of vegetation other than the forest.

‘A plant community may be defined as any naturally growing collection of plants which, for the purposes of the study of vegetation, can be usefully treated as an entity’ (p. 5). It is characterized by (1) *floristic composition* (list of species, frequency, constancy, exclusiveness); (2) *life-form*, significant because the life-forms of the dominants primarily determine the ‘look’ of a community, because they are an index of the habitat, primarily of climate, and important in so far as they determine the relationship of different members of the community to one another (subsidiary vegetation and tree canopy); (3) *structure* (lateral spacing and stratification) and (4) *habitat*. To the analysis of habitat there are devoted three chapters presenting descriptions and methods of measurement of the factors—climatic and physiographic, edaphic (soil) and biotic.

The classification adopted in the book is the one put forward by Clements. This regards vegetation as dynamic, as tending to change through a series of communities of increasing complexity towards a relatively stable type. There are in consequence communities of different status, and the practical importance of a recognition of this is well brought out by Professor Bews who shows that the burning of one type of grassland may yield desirable results in one series, but be definitely injurious in another (p. 346).

The definition of a plant community given above is very elastic—intentionally so. If, now, a plant community is an index of the habitat, then, argues Cajander, minor habitat variations which are reflected in tree growth will also be reflected in the accompanying vegetation, for there is no reason why the quality class idea should not be applied to growth forms other than trees, inasmuch as these also integrate the habitat factors. These minor differences in the larger ecological types Cajander calls Forest Types, which he characterizes by the floristic composition and 'ecologico-biological nature' of the mature, normally stocked stand. To support his idea Cajander and his school have accumulated much information statistical, biological, silvicultural, &c. Of the forest types which he recognizes in Finland a summary description of the vegetation is given and perhaps lack of space has prevented the author from giving a detailed characterization such as conforms to the method outlined above. A list of species, even with frequencies attached, is not adequate to characterize a community, and two habitats essentially similar, but remote from each other, may be peopled by quite different species, for an explanation of which we must consult their history.

While Cajander recognizes the adequacy of certain major activities, e.g. drainage, to change a vegetation type and of less potent factors, e.g. fire, animals, &c., to modify it, he seems to overlook the fact that the stability of his forest type, even under static climatic conditions, is only relative, and that change may be due to the action of the vegetation itself; and that the rate of change will depend on the species. Where soil deterioration is brought about one may well question the silviculture practised; but the fact of deterioration remains, and this must be reflected in the subsidiary vegetation. This does not invalidate the theory, but cautions against a too 'static' interpretation of the facts of nature, and aims at pointing out the necessity on the part of the ecologist and forester of finding out exactly how different silvicultural treatment (selection of species, systems, &c.) will cause departures from the normal, round which variations may be oriented. Just as grassland when grazed with rabbits or sheep or cattle will show differences in the relative proportions of the constituents and perhaps even the presence or absence of species, so forest types will show differences under the reaction of different trees to the habitat. This may not appreciably alter the essential habitat factors, but just as excessive grazing may result in soil deterioration, so the reaction of certain trees may tend to change the forest type. It is to the understanding of these reactions that Hesselman has devoted much work which he cannot reconcile with Cajander's, yet it seems to the writer that the points of view are not irreconcilable, for if we substitute a dynamic outlook for a static one, the crucial differences disappear.

Cajander and his co-workers have performed a much needed service to forestry in calling attention to the ecological basis of silviculture, to the forest as a biological unit in which the interrelations of the different forms of life should be carefully considered, and to the impossibility of expressing life in mathematical terms.

The Financial Return from the Cultivation of Scots and Corsican Pines, by W. E. HILEY, *Oxford Forestry Memoir* No. 6.

A Review by W. H. GUILLEBAUD.

ALL students of forestry will feel indebted to Mr. Hiley for his most interesting and lucid memoir bearing on the economics—using the word in the strictly financial sense—of coniferous planting. Compound interest formulae applied to forestry are the bugbear of the average student, partly because they are complicated *per se*, but also because they usually contain so many unpredictable factors that they appear to be quite divorced from practical affairs. The author has done a great service in showing how one of the standard formulae may be applied on common-sense lines to the solution of quite definite forestry problems.

The formula employed is that from which the rate of interest is obtained which, when applied in discounting all costs and income to the time of the initiation of a forest, make the two sides of the account exactly balance, in other words, the ordinary formula for the expectation value of the soil.

The values for P , the mean annual forest per cent., have been obtained in the present memoir by means of the ingenious 'Indicator Diagram' method previously devised by Mr. Hiley.

In the first and main part of his paper Mr. Hiley sets out to determine the financial yield from Scots and Corsican pine respectively, on the supposition that each of the variables entering into the formula can be determined within a more or less definite range to which he gives the name 'The Range of Probability'. Thus, in the all-important case of future prices, the yield is calculated on three suppositions—(1) that the present prices remain constant, (2) that they rise 1 per cent. per annum, and (3) that they rise $1\frac{1}{2}$ per cent. per annum. Evidence is adduced to show that the prospect of a future rise in prices is not unreasonable.

Similarly with the other factors, cost of establishment, cost price of land, cost of planting and of annual maintenance, the value of P has been calculated for a range of values of each of these variables and thus the effect of altering any one value while keeping the others constant can at once be seen.

The data on which the money tables have been based were obtained from the Forestry Commission's Yield Tables for Scots and Corsican pine; in the case of the latter species, the partial table published in Bulletin III required completion with the aid of further data.

The result of the comparison between Scots pine and Corsican pine has been to show that, owing to the greater production of the latter, it would be much the more profitable tree to grow assuming that the timber of the two species is of equal value. This is not likely to be the case, and trial with various values indicated that the two species will yield equal returns if, for first-quality plantations, the prices of Corsican pine are 59 per cent. of those of Scots pine.

The relatively low yield obtainable from even the best quality Scots pine plantation may come as a surprise to some readers; this yield would be still further reduced if, as in our opinion, the standard prices adopted for Scots pine are unduly optimistic for present-day conditions in many parts of the country.

An important fact brought out by the tables is the relatively small effect

upon the yield of quite a substantial increase in the cost of formation. Thus for Quality II Scots pine grown on an 80-year rotation, increasing the cost of establishment by 100 per cent. (from £5 to £10 per acre), only reduced the yield from 3.0 per cent. to 2.7 per cent., on the basis of standard prices plus 1 per cent. annum increment.

In the last section but one of the paper the author allows his imagination to play round such interesting problems as the effect of improving the site quality, so that, e.g., Quality I Scots pine is obtained in place of Quality II. He demonstrates that it would pay to increase the cost of formation by as much as £8 per acre if—but it is a very big ‘if’!—the soil quality could be thereby raised a quality class. At all events the illustration points the moral that it is not worth spoiling the ship for want of a ha’p’orth of tar.

Still more demonstrably profitable is it if a Quality I Scots pine site could be improved to grow Quality I larch, in such case from £10 to £20 per acre on soil amelioration would not be misspent. But to our mind the implication that, by the expenditure of a few extra pounds on the formation of a crop, the soil quality might be so improved as to be capable of growing a first-quality crop of a more exacting species savours of the chimerical. A more legitimate inference from the data given would appear to be the advisability of weighing up most carefully all the locality factors, so far as they are known, so as to arrive at a correct choice of species and silvicultural treatment.

It is clear that to plant Scots pine on a soil which will produce larch of equivalent quality class must involve a very considerable financial loss, which could sometimes be avoided at the cost of a little extra care and expense in the first instance. Such extra care might take the form, in some cases, of obtaining the best possible advice before deciding on the choice of species; in other cases much may be learned from thorough investigation of plantations in the district on similar locality types. Obviously too, in such species as spruce, which is often slow in starting, a little extra expense on cultural methods such as draining or turf-planting may be well repaid if a long period of initial check can be thereby avoided.

Untersuchungen über die innere Struktur und Entwicklung gleichaltriger natural-normaler Kiefernbestände. Von ERIK LONNROTH. *Acta Forestalia Fennica*, 30, 1925.

(Research on the Internal Structure and Development of Even-aged Normal and Natural Pinewoods.)

A Review by JAMES MACDONALD.

THIS is a paper of very considerable importance. It gives the results of a laborious research into the composition and development of pine stands in the southern part of Finland, carried out between the years 1918 and 1921, together with full descriptions of the material investigated and the methods employed.

The stands selected for investigation were classified on the basis of Forest Types, and were chosen from the principal types in that region, namely, the *Myrtillus*, the *Vaccinium*, and the *Calluna*. One important pine-type—the *Cladina*—was not represented, as it rarely occurred. Thirty sample plots were taken, ten for each Forest Type, and in their selection the author took care to see that they were quite pure, even-aged, and fully stocked, and in particular

to certify that the Forest Type was absolutely true. The ages varied from 14 to 159 years, and the plots were spaced over this range as nearly as possible at twenty-year intervals.

Full details are given of the situation, vegetation, and soil conditions of each plot, and it is interesting to note that all the plots are on sands either pure or with gravel, in many cases morainic debris. The author has devoted much attention to the classification of trees in the sample plots and, in a valuable preliminary chapter, he discusses this subject exhaustively. In the end, he adopts what is really a modification of Schotte's system, and, though this has decided advantages for the purpose of the investigation, for general purposes it can scarcely be described as marking a great advance on the earlier system. On this classification is based the whole of the subsequent work. Throughout the investigation the classes have been kept separate and separately studied. In this way the author has obtained important results, and has been able to follow in its successive stages the struggle among the contending trees and to throw light on the nature of the changes which are continually going on within a wood, and on the manner in which they are affected. He also shows that on the different Forest Types development does not follow exactly the same lines, but that certain interesting variations occur.

In carrying out the measurements sample trees were selected and felled, one for each tree class. This required twelve sample trees from each plot and the author did well, considering the age of some of his stands, to obtain 354 sample trees altogether.

The method employed in selecting sample trees is of some interest. For each tree class a diameter classification was made out and the mean diameter calculated. Then hypsometric measurements were taken of ten trees in each class, so chosen as to cover the range of diameters, and the heights obtained plotted against the B.H. diameters and a curve drawn. From this graph was obtained the height corresponding to the mean diameter. One sample tree was taken for each class with a diameter corresponding to the mean for the class and a height in young stands of within one-tenth metre of the mean height and in old woods of within a metre.

This method is undoubtedly an improvement on the method of selecting sample trees by ocular estimation of their height. It does not, however, take into account the relative numbers of the trees in the different classes. The results of the investigation are illustrated by an admirable series of graphs which set forth very clearly the main features of pine stands on the various Forest Types.

To quote Cajander's comments on this particular work:

'It is very remarkable with regard to several characteristics which bear on forest mensuration, that the sample plot data of the different Forest Types furnish well-marked, uniform series which do not overlap with one another, but, on the contrary, run on separate courses even with considerable blank intervals between them. Among such characteristics may be mentioned: the number of stems, basal area, volume per unit of area, mean height, dominant height and mean diameter.'

It is possible that the variations, which have been observed among the data collected from plots of Scots pine in Great Britain, may be explained on the basis of Forest Types.

There is appended a complete bibliography which gives the names of 258 authors, seven of whom write in English. These, however, are concerned not with Forestry but with Statistics.

British Bark-Beetles, by J. W. MUNRO, *Forestry Commission Bulletin* No. 8.

A Review by R. STEWART MACDOUGALL.

THIS Bulletin on British Bark-Beetles by Dr. J. W. Munro is a publication on which the author—till lately the Forestry Commission's Entomologist—and the Forestry Commissioners can be heartily congratulated. The bulletin extends to 77 pages of text with 26 text-figures and 10 special plates. It represents a great amount of hard, painstaking work on a difficult family of beetles of distinct importance in forestry, especially at the present time when the areas felled during the War are being replanted. Only an entomologist who has made a prolonged study of the Bark-Beetles, both in the woods and in the laboratory, could have produced this useful Bulletin. The plates are on special paper, while the species illustrated and the examples of their brood-galleries are reproduced in such magnification as to be of the greatest assistance to all interested in the subject.

Chapter I on General Biology calls attention to the two groups, one of them living in the bark, bast, and region of the cambium, and the other containing species which bore into the solid wood of the tree. There is a comparative account of the larval tunnels, the pupal chambers, the brood-galleries, and the feeding tunnels of the true bark-borers. The varying position of the feeding tunnels is interesting, a part of the biology which, for some species, calls for increased observation. The newly developed adult beetles may require to feed in order to ripen their reproductive organs, and in the case of the females to provide necessary reserve for egg-laying. This feeding may take place where the beetle has been developed, or the beetles may issue and feed on another part of the tree, stem, branch, or young shoot. It was once taught that death was the nemesis attending reproduction in the insect world, but we know that some bark-beetles may proceed to a new pairing, and the females to a new egg-laying, provided that they have a chance to recover from their exhaustion and the partial collapse of the reproductive organs, by a recuperation-feeding.

As regards life-history, it is pointed out by the author that there is considerable resemblance among the species of bark-borers. The bark-boring beetles are small species, and examination for comparison and identification requires the use of hand-lens and microscope. The pattern of the brood-galleries, however, may vary even in closely related species attacking the same tree, and it may be easier for the forester to recognize his enemy from the pattern of the galleries than from the beetle itself.

Attention is drawn to the wood-boring section of Scolytids—the interesting 'Ambrosia' beetles—whose larvae are nourished not on sawdust or boremeal, but on a growth of fungus which appears in their chambers. Is this growth accidental or is the presence of the fungus the deliberate work of the parent borer? The leaf-cutting ants of the tropics prepare in their underground haunts a soil of chewed-up leaves, with, it may be, added excrement, and rear on this garden, which is kept carefully weeded, a fungus on which the young are nourished. A queen-ant moving from the nest to found a colony of her own

carries with her, in a chamber under her pharynx, a plug of the ant-garden soil containing the desired fungus and uses this to start a new garden and colony. Is there similar deliberate work on the part of the 'Ambrosia' beetles? Schneider-Orelli believes that in *Anisandrus dispar* (the old *Xyleborus dispar* or Shot-borer, not uncommon in England on rosaceous fruit trees) the conveyance of the food-fungus is intentional, infection of the new galleries in the wood being by way of the beetle's mouth. The subject, with its complexities of more than one species of fungus, is full of interest and calls for intensive study. The bark-beetles have enemies, predaceous and parasitic, and a very useful summary is given of such enemies.

In Chapter II the economic importance of Scolytids is discussed, these beetles being reckoned for the most part as secondary enemies to be feared chiefly when the possible host trees have been weakened by defoliation due to insects, or by fungi or unfavourable weather conditions or bad culture with unfavourable environment. The importance of healthy trees is stressed, while it is pointed out that even healthy trees can in the case of mass attack by the bark-borers be ultimately so weakened as to render them favourable for brood purposes. The author believes *Myelophilus piniperda* (the Pine Shoot Beetle), and *Hylastes* (e.g. *H. ater* and *H. cunicularius*), which attack for feeding purposes recently planted conifers, to be the most injurious of our British Scolytids.

Prevention and control of bark-beetle outbreaks next receive attention, and Escherich's pronouncement is quoted on the importance of forest management as a controlling factor: 'The bark-beetle menace in general stands in inverse ratio to the intensity of the forest management. The higher and more intense the management, the less the menace.'

Chapter III is concerned with 'Structure and Classification', a number of original drawings helping to make clear the structural points, external and internal, which will enable the worker to make use of the classification keys which follow. The group of bark-beetles is a difficult one for the forester, the student, and the systematist, and numerous classifications have been offered by, for example, Eichhoff, Judeich and Nitsche, Hagedorn, Hopkins, Nüsslin, Leisewitz, Reitter, Redtenbacher, Swaine, Spessivtseff and Escherich. External characters have naturally been used, e.g. the varying antennae, the nature of the eyes, the shape of the pro-thorax, the elytra, the legs, while internal organs have yielded differences in gizzard, stomach, and genitalia. The fact is that all aids are necessary for the systematist and abundance of material, but the forester without, it may be, the use of the microscope and a certain skill in technique has to rely on his hand-lens for external differences, with the additional aids of the species of tree and the brood-gallery. Dr. Munro having the forester and general worker in mind gives a division of the bark-beetles into two Families, Scolytidae and Platypodidae. The Scolytidae Family is divided into three sub-families, Scolytinae, Hylesininae, and Ipiniae, and these again into their various genera.

In Chapter IV follow brief accounts of the British genera and species. This is a valuable chapter, and, taken in conjunction with the key for genera at the end of the preceding chapter, should prove very helpful to any serious student of the bark-beetles. I have tested the two chapters in my class work, and the workers, with, it is admitted, access to good lens and dissecting microscope, and with good material to work on, found the keys satisfactory. Fig. 5

of Plate II has by accident been named *Dryocaetes villosus*: this figure should be named *Dryocaetes autographus* as stated in the text on page 71.

In addition this chapter contains, under the various species, excellent first-hand field notes with suggestions as to treatment.

The Appendices follow, one giving a complete list of the British bark-beetles arranged according to their host plants, the other a bibliography of nearly seventy papers.

This Bulletin with its clearness, its fine illustrations, and its first-hand observations is distinctly the best thing to put into the hands of those interested in our forest trees, and their bark- and wood-boring enemies. At the modest price of two shillings and sixpence it should be in the possession of all our foresters.